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A waterspout in the Gulf of Genoa, photographed from the shipyards of Gio Ansaldo & C. at Sestri Ponente, Italy, January 13, 1917

Forecasting the Seasons

A Subject of Great Importance in Connection with Planting and Growth of Crops

By Alexander McAdie, Director of the Blue Hill Observatory

MAY, 1917, was the coldest May recorded at Blue Hill Observatory since records began, that is in a period of 32 years. And it seems to have been the coldest May in this part of New England in a period of 133 years if we may trust a built-up record to be referred to later. Strangely enough, May, 1917, was the warmest May recorded at London since records began in 1854 according to a letter in the *Times* of June 4th, from Dr. Mill, head of the British Rainfall Organization. This warm month followed a cold April and a remarkably cold winter and spring.

A few years ago such anomalies in weather would have passed unchallenged by the public; but now, with so much at stake, especially in connection with the planting and growth of crops, it is reasonable to ask of the aerographer if he can explain the cause of such unseasonable seasons? Can such abnormal conditions be foretold? And finally, has the war caused changes in the weather? The answers to these questions are briefly: Unseasonable seasons have occurred before and will recur; and are probably due to changes in surface circulation of the air, which in turn are due to displacements in what may be called "centering" of the hyperbars and infrabars, terms to be explained later. Successful forecasts of abnormal seasons seem possible when sufficient data are available and indeed a beginning has already been made. And finally, it does not appear that the war has had any direct effect upon rainfall or temperature over the battle zones or over the North Atlantic.

The search for enlightenment regarding the structure of the atmosphere and the laws governing the flow of air has been disappointingly slow. For the air is man's habitat. The first breath of life is an intake of air and physical life seems to be largely a matter of functioning properly as gas machines, that is, converting oxygen into dioxide, for when this ceases, life is over. As late as the middle of the seventeenth century it was not known that air exerted pressure. Galileo, the master mind of a remarkable age, passed on without comprehending this principle of aerostatic pressure. The experiment of his student Torricelli, the simple matter of a balance between a column of air and a column of mercury *in vacuo*, marks the beginning of our knowledge of the physics of the atmosphere. The analyses of Cavendish in 1784 mark the beginning of our knowledge of the chemistry of the air. And the beginning of our knowledge of the mechanics of the atmosphere in which we shall find the explanation of unseasonable seasons, dates back only to 1869 when Buchan published charts of mean pressure and prevailing winds for the globe. "Had the cautious Scotsman been a little more cautious," says the sapient Supan, who followed him in Germany, "we might still be without a chart of the isobars of the world."

The new science of Aerography, treating of the structure of the atmosphere, is essentially a study in Energetics. A given quantity of energy, most of it in the form of heat, is sent to us from the sun and according to the first law of thermodynamics does equivalent work. We must account for it. If there were no atmosphere, we know that the earth would receive something like two calories every minute over each square centimeter, the quantity of heat that would warm two grams of water one degree. But in reality only a third or even less of this reaches the ground. And so it begins to dawn upon us that in the atmosphere we have a mighty, yes, the mightiest of thermal engines. When we shall be able to survey it as a whole and keep account of the intake of energy and output of work, then we will be able to explain abnormal seasons and state the reasons for unusually heavy rains and prolonged periods of hot or cold weather. It is, however, beyond the power of any one man to assemble and digest the data representing fairly the amounts of heat received and the work done in moving the air or causing winds for even a small area. Fortunately coöperation among weather bureaus permits of a certain coördination; and this year there has been brought to a successful finish, the most promising survey yet made of the bottom level of the atmosphere for the land surface of the globe. Unheralded and as yet all unknown to the public, the Réseau Mondial (or world net), gives the conditions for 1911 and makes possible certain deductions regarding the control of seasonal conditions by the large pressure areas sometimes called "grand centers of action" or more simply infrabars and hyperbars. And how was this survey accomplished?

It fell to the lot of the Director of the British Meteorological Service at an international conference held in Berlin in 1910, to present a sample survey for a single month, namely January, 1905. This was an attempt to meet the clamor of solar physicists for world-wide data. So much work was necessary, however, that the project of a yearly survey would have certainly been dropped but for the fact that in the succeeding year the summer was unusually dry and warm over northwestern Europe, the northern Atlantic and the northeastern part of our own country. Aerographers were called upon to explain and so it was decided to attempt a world survey for 1911. If we could have the surveys for 1915, 1916 and 1917 there is little doubt but that the causes of the unusually wet periods in 1915 and 1916, the abnormal cold of the spring of 1917, and the abnormal drought in Germany and central Europe of the present summer, might be clearly traced to certain changes in surface and upper winds due to oscillations of the great pressure belts.

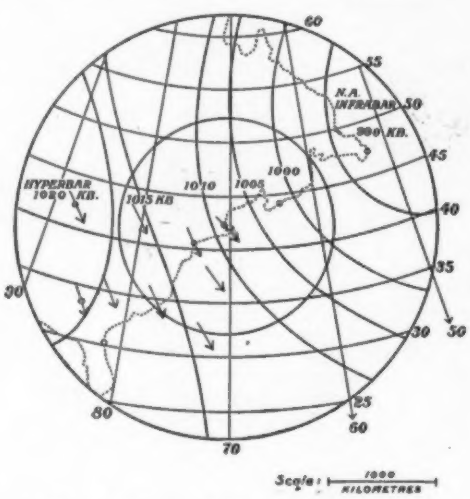


Fig. 1. Pressure during dry spring month

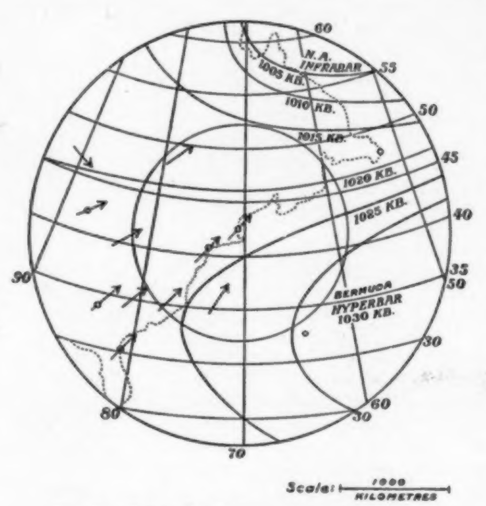


Fig. 2. Pressure during wet spring month

NORTH ATLANTIC SEABOARD

From an insistent public comes the question "Is the war the cause of the change in weather? If not, what is?" We shall try to show that so far as data are available there is no evidence that the war has had any direct effect upon weather conditions and that abnormal conditions in one region are closely correlated with abnormal conditions of an opposite type elsewhere; and that the most probable explanation lies in the oscillations, "swings" or "see-saws", as they have been called, in the atmosphere on a large scale, counterbalancing each other as it were. There is no permanent set or positive change and no need to seek explanations in extra-atmospheric causes, nor yet in man's efforts. Much light is thrown upon the cause of dry and wet springs and also cold or backward springs by a study of the prevalence of the winds in a given district for a number of years. This has been done in a recent volume issued by Harvard College Observatory on "The Winds of Boston," from which it appears that there *is* a direct relation between the duration of the west wind and dry conditions. March 1915 was the driest March known and during that month there were 310 hours or twice the normal duration of west wind. The current May was the coldest recorded at Blue Hill Observatory in 33 years and if we may trust a record built up from observations made as explained below[1] it was the coldest May in 130 years. There is, however, no reason to ascribe its cause to the war, for there have been other cold springs when no wars were in progress. Thus the spring of 1816 was very cold. It was known in New England as "the poverty spring" and the year itself as "the year without a summer." Other cold Mays were in 1815, 1832, 1841, 1850, 1882 and 1907.

Solar activity has often been suggested as the direct cause of abnormal weather. We can not, however, trace any direct relation between the cold periods which we have mentioned and solar phenomena, so far as known, for the years of maximum sun-spot activity were 1788, 1805, 1816, 1830, 1837, 1848, 1860, 1871, 1884, 1894, 1906 and 1917. The years of minimum frequency were 1811, 1823, 1834, 1844, 1856, 1857, 1867, 1879, 1890, 1902 and 1913.

Sun-spots are areas of diminished radiation or lower temperature, and the sun is now known to be a variable star whose output varies not only over long periods but over comparatively short periods; nevertheless we can not yet link up cold springs and changes in the solar output. Whatever the effect may be upon the atmosphere as a whole, it seems likely that the small variations in heat and moisture which make the difference between seasonable and unseasonable weather have their origin in the atmosphere itself and are not of extra-terrestrial origin. And thus looking nearer home, we find in the water vapor and in the control which it exercises over diurnal and nocturnal radiation a probable cause.

Every one who has a garden knows that on a cloudy night there is little danger of frost, and the temperature will not fall so low as on a night when the sky is clear and the wind is lulled. A simple enough proposition, for the aerographer knows that low lying clouds of moderate density will cut off as much as 80 per cent of the outpouring radiant energy called heat. Even the high cirrus or ice cloud which may escape notice will reduce effective radiation as much as 10 per cent. So in a picturesque way we may say that water vapor is the stuff from which is woven earth's various garments, some heavy in texture, some light as veils; but all serving to conserve the ground's supply of heat.

Another question often asked is: "Do volcanic eruptions cause abnormal weather?" Unquestionably they do within a limited radius, where there are marked inrushes of air and definite areas of excessive rainfall. Eruptions are also effective indirectly because the dust which is projected into the higher air strata serves as nuclei of condensation as shown in the formation of high clouds. Before long, we shall probably have some definite data on the relation of volcanic activity and abnormal seasons; but in the meantime it can be stated that the latter half of the year 1912 seemed to show a decrease in the direct solar radiation received at the earth's surface following the eruption of Mt. Katmai in Alaska in June. While the change was marked in the northern hemisphere, the volcanic dust apparently did not cross the equator and drift into the high air over the southern hemisphere for there was no indication of its presence or effects at Arequipa, Peru, where records of intake of heat and amount of vapor are kept by the Harvard Astronomical Observatory and the Smithsonian Institution.

Finally, comes the question, "Is the heavy firing on the western front the cause of the excessive rains of last year?" The answer is No, no more than it is the cause of the drought of this summer. The dates of heaviest firing have not been accompanied nor followed by unusual rains either in the zone of fire or within moderate distance. The rains seem to have come and gone without regard to the firing. Naturally one will associate any stormy weather occurring near the date of a battle with the battle; but may easily overlook that in some cases the rain begins before the firing. Or again rain

[1] As early as 1750 the Corporation of Harvard College settled an account for rain gages; and nearly all the Hollis professors of Natural History were ardent meteorologists. The Meteorologic Diary of John Winthrop runs from August, 1749, to April, 1779. Dr. Holyoke's records began in 1786 and were continued without a break for 35 years. Dr. John Jeffrey's records began in 1774 and with interruptions run to 1816. The Rodman records made at New Bedford began in 1812 and are without break to date. There is also a record at New Haven dating from 1779 with but few intermissions.

falling within two or three days of a battle is attributed to the battle when in fact the rain area can be traced far to the west several days in advance. A notable instance of this confusion of event and cause is the battle of Gettysburg often quoted as directly causing rain. The first three days were clear while rain fell on the fourth day or after the battle was over. A slight study of weather sequence in that locality will show that such a sequence is entirely normal. In the past three years there has been unusual opportunity by explosions in munition plants and depots to study the concussional theory of rain-making; and evidence adverse to the theory steadily accumulates. A close watch has also been kept on some other problems such as the audibility of gun-fire and the aberration of the sound with different atmospheric conditions. A cloudy sky for example appears to be more favorable for the travel of sound than a clear sky. Along the coast of England the sound of the guns in France can be heard more distinctly when light northerly winds prevail than when southerly winds are blowing, although one would expect the opposite. It seems that at such times there are south winds higher up in the air and the sound waves are refracted downward. Such a reversal of air currents is found as a rule in advance of rain. Under such conditions when distant gunfire is heard and is followed in a short time by rain, the hearer naturally connects the rain with the gun-fire, whereas it is a question of the structure of the atmosphere. It is the juxtaposition of the air streams and not the concussion that results in rain. What then is the process of rain-making? Simply a cooling of the water vapor. An ice pitcher on a warm day is a modest little rain-maker. There is needed an ample supply of vapor and a cooling commensurate with the degree of saturation. Cooling may be brought about in different ways, as by contact shown in the case of the ice pitcher, or by radiation as in the case of dew-making, or by expansion following uplift as in summer showers or by mixing as in coast fogs and coast rains. In studying floods in our great river systems we find in advance of the heavy rains, steady warm, moist air streams moving north, and west of these still more energetic cold streams of air moving south. Over the British Isles when a westerly current has an easterly current south of it, there seems to be little mixing and little rain, the weather being in the main pleasant. But if the westerly current has an easterly current on its northern side, storms follow.

Space does not permit us to refer to the work of aerographers at home and abroad showing how closely the character of a season is determined by the character of the circulation of air. Thus dry winters in California, the usual rainy period, can be forecast with fair success. This means everything in a land where raindrops are counted as golden drops, for the crops depend upon these early and later rains. A dry winter means distress, while copious and seasonable rains mean bountiful harvests and consequent prosperity.

So then we may dismiss the question of the effect of war in making unseasonable weather; but we can not disregard the rather more important question—the effect of an abnormal season upon the operations of man, including war. An unseasonable continuance of south and east winds over central Europe due to a temporary displacement of the continental infrabar may cause deficient rainfall if not drought during the growing period and so affect the harvests. And a scant harvest now as in the past may be a more decisive factor in bringing war to a close than fiercely fought campaigns and hard earned victories on the field of battle.

The Internal Secretions*

Chemical Factors in the Regulation of the Organism

By Percy G. Stiles

ONE need not be a profound student of science to appreciate that the coördination of activities is a most striking fact of animal life. What happens in one place is adapted to what is occurring at another. It may fairly be claimed that each part acts more distinctly for the good of the whole than for its own advantage. Clearly, this could not be the case if there were not some mode of transmitting influences from organ to organ.

When one considers the possible means of such transmission the nervous system is at once suggested. This wonderful structure is so fashioned that, conceivably, any part of the body may definitely affect any other. It is in this respect like a telephone exchange which affords to each subscriber the opportunity to communicate with any other. The nervous system has long been looked upon as the essential instrument of coördination. A second possibility has lately become unexpectedly prominent. It is the transmission of chemically active products through the medium of the circulation.

Such products of the tissues are usually called internal secretions. A compound added to the blood by one organ will, within a minute, be quite uniformly diffused over the whole body. There is no way to limit its distribution and bring it all to bear upon a restricted portion of the system. In this respect the interchange of influences by means of internal secretions lack the refinement and precision which characterize the nervous correlation. We have to do with a set of drugs which, like those administered by the physician, must be offered to all the tissues—to those which seem indifferent as well as to those which are evidently responsive.

The internal secretions have proved to be more numerous and more important than anyone would have predicted fifty years ago. The subject will doubtless occupy a larger and larger place in future expositions of physiology. A brief summary of the matter as it now appears may be attempted. The part played by these chemical messengers can conveniently be stated under three headings.

I. *Internal Secretions and Growth.*—Normal development cannot be accomplished unless the blood receives certain contributions from several small organs. One of these is the thyroid in the neck. If this fails to play its part the growth of the child is arrested. Nor is the result a simple dwarfing of stature; the proportions and features are grotesque and the mental retardation parallels the physical. The proof that this condition (cretinism) depends on thyroid failure is satisfactory: the mingling of dried thyroid substance from animals with the food of the cretin gives a marvelous impulse to its development. The treatment, fully continued, may nearly counteract the defect.

Another organ, which radiates a well-marked influence upon growth, is the pituitary body, an inconspicuous appendage upon the under surface of the brain. Its action may be perverted by disease with the result that there is over-growth, tending toward the gigantic. In other cases of pituitary disorder there may be malformation of the bones. The effect on the configuration of the face may be startlingly uncouth. Even in adult life these changes may set in.

The thymus, a mass of tissue high up in the chest, is believed to regulate growth in some obscure fashion. Much more distinct are the relations which exist between the reproductive organs and development. The dependence of a symmetrical type upon the normality of these organs is familar. It should remind us that any group of cells have more than one function; in this case the dispensing of internal secretions reacting upon the individual goes along with the preparation of the germs of the coming generation.

II. *Internal Secretions and Maintenance.*—The thyroid and the pituitary body which so profoundly affect the course of growth continue to exert a regulation upon the processes of mature life. Loss of the thyroid by an adult leads to a serious depression of health with physical signs recalling cretinism. Loss of the pituitary—if we may judge from the case of the lower animals—cannot be survived.

At least two other organs make contributions to the blood which cannot be spared for any length of time, the pancreas and the adrenal bodies. The pancreas was long known to elaborate an important digestive juice. But it is like the organs of reproduction in that it does not merely separate something from the blood but adds something to it. Removal of the pancreas without doubt impairs the digestive capacity but this result is overshadowed by another: all the tissues lose the power to oxidize, and so to profit by, their chief fuel which is sugar. This loss is the central fact in diabetes. When developed to its limit the power to use fat is also abolished and the problem of nutrition becomes hopeless.

At the back of the abdominal cavity, above the kidneys, are the paired structures known as the adrenal bodies. Insignificant as they appear they are vital organs, the removal of which is followed swiftly by prostration and death. Something must go out from them which gives tone and efficiency to more than one system. When the adrenals are gradually wasted by disease the failure of strength corresponds with the degree of their destruction. Their extracts do not successfully compensate for the lack of living cells; the body seems to need a slow, uniform delivery of this internal secretion and periodic dosing does not prove equivalent to the natural condition.

III. *Internal Secretions at Particular Times.*—So far we have spoken as though internal secretions were set free slowly and steadily, having their effects throughout long periods. It remains possible that they may be discharged to the blood somewhat suddenly under peculiar circumstances. We have the best of evidence that the adrenals can thus be thrown into a temporary activity far beyond their ordinary performance. The particular occasion for this is one of stress and excitement. It has been clearly proved that as such times the chief product of the adrenal cells (adrenin) is increased in the blood. It has also been proved that this internal secretion confers upon an individual the utmost command of his physical resources. There is ground for the belief that the thyroid as well as the adrenal tissue has special awakenings to accelerated production.

We began by stating that one organ of the body may influence another either by nerve-impulses or by secretions carried in the blood. These two types of action admit of some combination as will now be obvious. The temporary arousing of the adrenals in emergencies is certainly due to a stimulation effected through the nervous system. The thyroid is probably under a similar nervous government. Hence, in these two cases if not in others, a reaction that is first mediated by the nervous system may be completed under the influence of internal secretions.

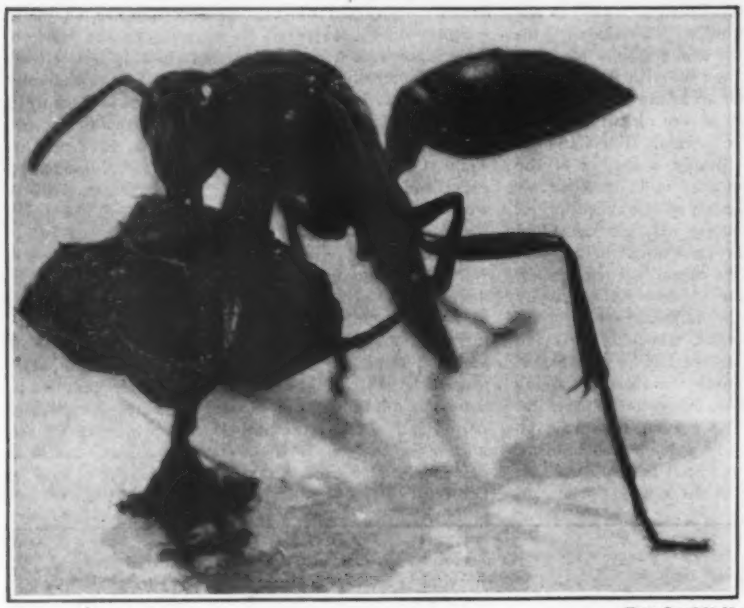
The medical doctrines of the Greeks centered upon the theory of the Four Humors, according to which health depended on the maintenance of right proportions among four essential ingredients of the body-fluids. It is interesting to observe that we are once more giving place to views very suggestive of the old. We believe not in four but in a considerable number of active substances which must be rightly balanced. Abnormal conditions may arise either from deficiency or from excess on the part of any one of these.

It is not long since physicians assigned their patients to groups according to "temperament," the lymphatic, the sanguine, and so on. The scientific equivalents of these designations seem to be connected with the organs of internal secretion. The diagnostician can now recognize in a peculiar type the evidence of an overactive thyroid, in another the signs of pituitary excess. When one looks at the pictures of men suffering from serious diseases of these organs one is constantly impelled to say, "Why I have seen people who looked like that!" It is fair to suppose that for every bad case of this class there must be many mild ones. Most of these will not be recognized as pathological. As individuals can be found to suggest all types of insanity while yet keeping within the province of the sane, so we can see hints of departure from the ideal balance of the internal secretions in those who are still effective members of society.

*From *Science Conspectus.*

Electric Heating of Steam Boilers

BANKED boilers in an auxiliary steam plant, acting as reserve for hydroelectric generators, involve considerable fuel consumption and constant supervision. When surplus electrical energy is available, which is especially the case in summer, it may be applied usefully to keeping the reserve boilers hot. In the Letten station (Zurich municipality) two water-tube boilers, each of 270 sq. m. heating surface, have been electrically heated since September, 1915, and with such success that the system is being applied to other boilers. Cast-iron resistances are mounted on a rolled steel frame which fits on to the grate; the furnace mouth is closed by a terminal plate with observation window. In a double flame-tube boiler there are six sections of resistance (pairs in series) in each tube. All dampers are closed while electric heating is in progress. The maximum temperature of the resistances does not exceed 600° C. A double boiler with 17 cu. m. water capacity, supplying 1,720 kg. steam per 24 hours at 4 to 7 atmos. for feed pumps and keeping pipes and machines hot, consumed 84 to 86 kw. The three boilers heated electrically supply 5,630 kg. steam per day, and consume on the average 1.31 kw.-hrs. per kg. of steam. At ordinary prices electric heating of boilers is prohibitively costly; the system is only applicable where the power would otherwise go to waste. Working pressure of 7 atmos. was reached 100 hours after commencing electric heating. The distribution of heat is approximately as follows: Resistance elements, 450°; 10 cm. above the heater, 315°; over second row of water-tubes, 185°; over fifth row, 173°; behind superheater, 165°; over damper, 157°. When the boiler is required to take up load, the electric heater is withdrawn and coal firing resumed; within half an hour full output can be thus attained.—*Science Abstracts.*



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The life history of a wasp shown in pictures

On the left Queen Wasp as seen working upon her first spring nest. The queens hybernate in the fall in a pregnant condition and lay the foundations of wasp empires during the first days of spring. This first nest is entirely constructed by the queen from wood fibre scraped from old boards or weathered buildings. She fashions a few cells and lays an egg in each. These hatch in a few days, bringing to light white maggots, which the queen mother tenderly feeds and cares for until they reach maturity, when they take up the care of the nest and the queen retires, her only duty now being the laying of more eggs as the nest grows.

On the right the Queen is shown in the act of laying. The egg is seen just emerging from her ovipositor in a newly constructed cell. The nest always hangs suspended by a central stem and is placed under the overhanging roofs of buildings or similar situations.

Engineering in the Great European War*

Former Tactics and Strategy Have Become Subordinate Factors

By Frank W. Skinner, C. E.

ONLY casual observation is necessary to show that the lines of the great war now raging in Europe are almost wholly determined by engineering principles and that engineering considerations, construction and operations so dominate the whole field and influence its results that warfare is conducted on a radically changed basis, and that some of the most important features of former times are either nearly discarded or have lost their controlling character, so that personal bravery, spectacular heroism, former tactics and many carefully planned evolutions and strategic movements of great bodies of troops have become subordinate factors.

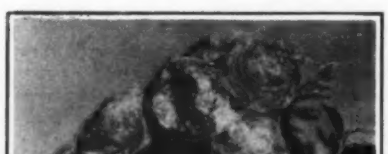
The general truth of these assertions may readily be verified by a careful review and simple analysis of the current reports of the conditions, methods, results and progress of the war. It is vastly emphasized by a visit to the belligerent countries and by opportunities of inspection in the War Zone, both of which were accorded to me during several months of last spring, summer and fall.

Important interests demanded my continued presence in England and in France, where I spent almost equal portions of the time in London and Paris, making many trips across the channel, spending several weeks in the military zone with headquarters at Havre, the base of the British expeditionary force, and occasionally visiting Rouen, Dieppe, Boulogne and other important cities. My business and credentials provided exceptional facilities for privileges with the war department of the British, French and Belgians and numerous interviews with officers, soldiers and Red Cross surgeons and nurses of these nations.

The evidence was to me overwhelming that this great conflict is essentially an engineer's war with the results to be determined by the perfection, completion and abundance of engineering preparations, equipment and training, modified only by the exhaustion or vital political conditions of one or more of the belligerent countries.

Methods of warfare have been revolutionized and results magnified beyond comprehension by several engineering factors among which it is hard to say that anyone is first in importance or effectiveness. The wonderful system of German railroads, designed for military purposes and operated with astonishing accuracy, regularity and efficiency that put to shame the uncertain, unreliable and indifferent service on many of our own great railroads, is certainly one of the greatest

*The *Cornell Engineer*.



Looking into the front of a wasp's nest late in the summer. The nest has now grown to an empire, many broods having been raised and each in turn has labored to increase the colony. In each of the cells we see the face of a young wasp peering out. They are fed in this position by the older wasps until full grown when they spin a cocoon in their respective cells and undergo a transformation that brings them out some weeks later as perfect wasps.

factors of the situation. It enables the Kaiser to hurl his armies from frontier to frontier of a great empire and attack and repel those on opposite boundaries in so short an interval between engagements that the same forces or troops might almost be considered as simultaneously occupied in different places, thus practically doubling the efficiency of his armies and enabling his offensive to be carried on with overwhelming vigor, supplemented by the wonderful preparedness and devoted loyalty of his troops and very much retarding the earlier progress of his adversaries.

The latter campaigns have not neglected to provide for rapidity and safety in defeat as well as in advance by the construction of wonderfully excellent highways closely following the invasion of foreign territory and providing alike for constant supplies and for rapid retreat in case of emergencies. This rapid and extensive construction of heavy roads involves a considerable degree of skill and experience in handling materials and in building bridges, making fills and excavations and providing adequate operating facilities. All sorts of structures including pontoons, trestles, embankments, and in some cases even cableways were utilized and at Havre the preparation of the Allies were so complete as to include large quantities of steel girders for canal-lift bridges equipped with differential hoists and lifting columns ready to be installed as units over the Belgian canals where it was desirable to maintain an interrupted communication both by highway and waterway. Complementary to these provisions are massive power machines for destroying roads in the rear of a retreating army.

Another most important structural feature is the military trench which now protects almost the entire length of the 2,000-mile battle fronts. As both sides are protected not by a single line but by multiple lines, three, four, six and even ten deep, and as these lines are never straight but are always violently zigzag, it follows that there are many thousands of miles of this sort of construction which varies from that of a 3-foot trench 5 feet deep and excavated through soft earth, to one as much as 30 feet deep excavated in harder material, besides many miles of rock trenches, particularly those in the Swiss fortifications of great mountain passes which are intended to defend them from the violation which has crushed Belgium. A large quantity of these trenches are quarried out of the solid granite of the Alps.

Some of the earth trenches are quite elaborate and include one, two or even three tiers of subterranean houses burrowed out of the sides of the trench to afford eating, sleeping, living rooms and officers' quarters for the defenders. The living quarters as well as the magazines for storage of explosives and ammunition are heavily protected by tier after tier of roof logs covered with several feet of earth or gravel; while the vertical sides of trenches in soft ground are sheeted in various ways with planks, mattrasses, branches of trees, and even with concrete walls.

Part of my errand abroad was the successful presentation to the war departments of the Allies of a system of very light interlocking steel sheet piles of the "slip joint" type, each unit of which was about 12 inches wide and 6 feet long and weighed less than 20 pounds. These could be almost instantaneously placed on both sides of the trench forming continuous interlocked walls easily driven a few inches into the earth at the bottom and covered and braced by an inclined surface of the same material automatically fixed in position so as to

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The life history of a wasp shown in pictures

At the left are cells of the wasp's nest cut open to show the eggs as deposited by the queen.

At the right is a cross-section of a wasp's nest showing a young wasp still in the feeding or larval stage and a pupa or wasp that is nearly ready to issue into the world and take up the work of the empire. In the fall the nest has grown to great size. At length the old queen dies and the young wasps fly away from the old home to find their mates. The working members of the colony perish from the cold. The young males also die after mating and the fertile queens hybernate once more to await another spring when each will found a new colony.

afford complete shelter and protection for the trenches and their inmates and permit a heavy loading of earth and brush on top to conceal them from aviators.

Another purpose of my visit was the introduction of portable steel houses for field hospitals, officers' quarters, ammunition storage and for sheltering refugees. A 10 × 24-foot house complete, having two rooms, four steel-sash windows and two steel doors, was made of $\frac{1}{16}$-inch metal full height wall panels instantly interlocked by the pantented "spring-lock" connections on the edges of the plates. It weighed about 46,000 pounds, and could be transported anywhere on an automobile truck and could be erected ready for use in less than two hours by four unskilled laborers without the use of any tools, not even a hammer or a bar, and without requiring any bolts, screws, rivets, wedges or separate connections. The houses were especially favored by the Belgian government who placed an order for a large number of them—there was nothing elaborate or remarkable in their design or construction, but they emphasized the efficiency of careful engineering in a simple and practicable design that avoided ordinary difficulties and provided for great strength and durability with speed and economy of transportation and erection.

FIELD ENGINEERING

To the engineer corps is assigned the most dangerous duty of building the barbed wire protection in advance of the trenches as well as the field telephone and telegraph lines which are installed with wonderful rapidity by squads of men on horseback who often hasten across exposed territory under enemies' fire. The engineers have also devised many methods of penetrating or destroying these formidable wire entanglements, and of course direct and execute numberless mines which are driven in advance of the first line trenches and charged with high explosives to blow up the enemy trenches. When countermines are detected approaching the mines they are sometimes destroyed by a method of forcing hollow pipes underground where a tunnel could not be drifted, and then by exploding small charges of high explosives in the ends of these pipes.

Among the offensive factors of the war nothing has greater military effect than the wonderful ordnance which have a maximum caliber of no less than 17 inches and a maximum range of 24 miles. The great siege howitzers weighing 100 tons cannot be transported as units and have to be divided and the carriages and gun barrels hauled separately over special roads by enormous motor cars which generally carry with them a crew of 30 to 50 men to serve the great monster. The gun itself, which is usually in a concealed position, perhaps behind a mountain, requires great accuracy of installation and must be placed on a steel and concrete base of large dimensions.

The moderate-size field batteries, as well as those of large caliber are remarkable for the recoil mechanism consisting of concentric cylinders with hydraulic plungers and spiral springs that not only absorb the energy of the recoil but store enough of it to bring the gun back almost instantly to its original position with such wonderful accuracy that it does not have to be re-sighted at a fixed target and permits the firing of as many as 30 rounds per minute against 4 or 5 by the old method. The projectiles attain a weight of 2,800 pounds and carry enormous quantities of such high explosives that no structures or fortifications have been found able to withstand them. If they should be brought to bear and continue to play on any fort it is sure to be rapidly demolished. The projectiles have a penetration of 26 inches of steel armor plate, 20 feet of solid oak timber and 21 feet of granite and concrete masonry, making a total of more than 43 feet to which is to be added the tremenduous energy of explosion.

The shrapnels, bombs and grenades are made with great accuracy and do vast execution. They are provided with firing devices or fuses to regulate their explosion to the exact moment required as they reach their mark and scatter their missiles and fragments of shell in every direction in the limits of a great cone or sphere.

The whole of the North Sea, many parts of the Mediterranean and numerous other ports are planted both for offensive and defensive purposes with contact mines very ingeniously constructed so that when thrown overboard in water of unknown depth they easily anchor themselves accurately at the required distance of 10 to 20 feet below the surface. Other mines are anchored close to the bottom and can be released from shore and rise to a certain distance below the surface when the enemies' ships are in sight. Still others may be anchored in the required position at or near the surface and exploded only by electrical devices automatically operated on shore by combined movements of telescopes of two simultaneous observers that follow the course of the ship until it is directly over the spot where the mine is placed.

The most dreadful of the engineering devices is the submarine which is now reported to have attained a maximum length of 400 feet and a displacement of 5,000 tons making it in reality a submerged cruiser provided with disappearing bulwarks and deck guns as well as with the terrible submerged torpedoes which are fired at a velocity of about one mile a minute and are effective for a three-mile range or farther. The torpedoes, 21 inches in diameter, are long pointed steel cylinders containing in the forward end a heavy charge of high explosive, and being equipped in other separate compartments with a supply of compressed air operating the engine driving its propeller and with gyroscope and special chambers for maintaining its equilibrium and horizontal and vertical position. One of these will blow up a full section of a ship and destroy the engine room and boilers or damage the hull so much that in most cases it sinks with great rapidity notwithstanding the watertight bulkheads. A freight ship attacked by a submarine torpedo was injured only in a single compartment, and the bulkheads proved efficient to enable it to reach dry dock where it was repaired and a photograph of the injured section was taken which showed almost the entire side of the ship torn away at the point where the torpedo struck it.

ZEPPELINS

A still more terrible engine of destruction is the improved Zeppelin which, however, thus far has not proven efficient for military purposes other than that of observation, and has concentrated its hideous power on the destruction of women, children and other civilians in helpless unfortified cities. These great air ships nearly 500 feet long and 75 feet in diameter are of marvellous construction, with riveted metal framework containing a large series of balloons and air bags which together with the powerful propellers and the rudder planes make it dirigible under ordinary conditions. It has a horizontal speed of from 50 to 80 miles per hour together with the valuable ability of rising at the rate of half a mile per minute on a very steep incline by the combined operation of propeller planes, gas heating and the ejection of water ballast.

Zeppelins usually carry machine guns for defense purposes and have a crew of 15 to 30 men in armored cabins. They are also equipped with great quantities of delicate instruments and wireless and searchlight apparatus. They carry numerous incendiary and explosive bombs to rain down on the defenseless cities. A fleet of three Zeppelins raided within one block of my London lodgings and caused terrible havoc in the course of 20 miles which was covered well under one-half hour. A single explosive bomb wrecked all of the five-story crowded tenement building, facing on an open square, in the center of which the bomb fell making a deep crater in the ground and devastating the peaceful neighborhood at midnight, when most of the buildings were crowded with sleeping families.

The more numerous incendiary bombs ignited entire streets simultaneously so that a total harvest of many hundred innocent victims must have been reaped where for obvious political reasons, the death of only 56 people was admitted in the official reports. The terrible destruction of this and other raids on London was due not only to the efficiency of the Zeppelins but to the circumstances of their being able to travel unseen through the fog or clouds two miles above the great city 30 miles in diameter and containing in its congested areas 7,000,000 inhabitants—distributed so uniformly that although it was almost impossible to reach any special mark from the Zeppelins, on the other hand, the continuous cataract of explosives which they dropped could not fail to be horribly effective.

Another element of much more pronounced military efficiency is the aeroplane, which has considerable offensive value, constitutes the only practicable city defense against Zeppelins, and which has proved invaluable for scouting operations, reconnaissances, raids and observations behind the enemy's advance line, military photography, etc.

Some of the aeroplanes have a speed of more than two miles per minute, while others have been constructed

of such power and dimensions that they carry a crew of 8 men in an armor plated cabin and are equipped with four rapid fire guns of good caliber and two smaller machine guns, besides carrying large quantities of bombs. As the dimensions of the aeroplanes are continually being increased and the equipment perfected there is no doubt that they will soon become an even more important and valuable factor of modern warfare.

The above are only the more noticeable applications of engineering to military affairs. The whole field is covered by engineering constructions, machines, and operations, which have been perfected to a wonderful degree by the highest and best skill in the world utilizing the unlimited resources of vast empires to produce offensive and defensive weapons. Of all the great nations the United States alone has been dormant and indifferent and has accomplished almost nothing in this vital field.

We are today actually defenseless before the great powers of the world. We have not even resources or equipments sufficient for defense against Mexico if the latter efficiently utilizes the present forces which if concentrated and properly handled could make a terrible invasion of the United States and could not be conquered in their own country by five times our entire present army. The small punitive expedition recently sent there is pathetically feeble and ill-equipped.

At the end of the great European war, no matter which side is victorious, there will be left, dissatisfied and unoccupied, not less than 10,000,000 veteran fighting men armed and equipped with the most efficient weapons and with abundance of ammunition. They will also have enormous quantities of great field guns, a thoroughly perfected navy, and innumerable submarines, Zeppelins and aeroplanes, and are skilled in the use of them all.

The Electrical Properties of Gases—III.*

Which Enable Important Problems in Physics To Be Studied

By Sir J. J. Thomson, O.M., P.R.S.

CONTINUED FROM SCIENTIFIC AMERICAN SUPPLEMENT No. 2168, PAGE 39, JULY 21, 1917

In opening the fourth lecture of his course on the above subject, Sir J. J. Thomson, said that in his last lecture he had described a possible way in which thunderstorms might arise. His lecture had been so quickly succeeded by a very violent storm that it might almost be considered as an experimental illustration. Some photographs representing an artificial flash or spark and actual lightning flashes might be of interest. The photograph of the spark was represented in Fig. 1, while Fig. 2 represented a typical flash. The principal point to which he would draw attention was that the main discharge was accompanied by branches developed laterally from point to point. It would also be noted that the flash was very far from straight, though no doubt part of the crookedness apparent was due to foreshortening. In Fig. 3 a multiple flash was represented, the first flash being followed quite quickly by a number of others, some of which appeared to be analogous to a steady discharge much more like that obtained in a vacuum tube than to a spark. This, the lecturer continued, was to be expected, since the original flash ionized the gas, which retained its conductivity for a little time. If other flashes followed immediately after the first they would get through without having themselves to put the air into a conductive condition. He had suggested in his last lecture that globular lighting was the result of just such an ionization of the air by a flash of the ordinary kind.

The subject of thunder had not been the subject of so much attention as had lightning. As shown in his last lecture, the passage of a spark through air was accompanied by a wave of high pressure, which could be detected by a jerk in the level of a water gage connected up to a bulb through which the spark passed. A similar explosive wave was generated along the whole line of a lightning flash. It was usual to attribute the "roll" of thunder to the reflection of this wave from clouds, and this might, no doubt, play a large part in the phenomenon. It was, however, to be noted that Wilson had shown that the length of a flash was some six miles or so. It was evident, therefore, that to an observer, favorably placed, the sound would be drawn out for the time required by sound to travel over six miles. Hence, even without the aid of reflection, a peal of thunder might be considerably prolonged merely owing to the difference in the length of the path over which the sound had to travel to the observer. Moreover, in certain cases the flash might take such a direction that the part of the path nearest to an observer might lie somewhere about mid-length. In that case some points at the beginning and end of the flash would be equidistant, and the disturbances from them would reach an observer simultaneously, accentuating the sound into a crash.

It might be noted in this connection that our atmosphere had a natural periodicity of its own, and a flash six miles long might perhaps be capable of exciting vibrations of the atmosphere as a whole. It would be of interest to see if any kind of pressure wave could be detected after the passage of a flash.

Lightning conductors might be regarded from two points of view, which should be kept more distinct than they frequently were. From one point of view a lightning conductor might be regarded as a decoy to draw fire and pass it safely to earth. It might also, however, be designed to prevent any discharge at all by reducing the intensity of the electric field in its neighborhood. It then acted in an entirely different way. If used as a decoy it was very necessary to make sure that the path offered by the conductor constituted the shortest possible distance between the top of the conductor and the ground. With an impulsive current such as a flash of lightning the electrical resistance of a conductor was not of moment, there being no material difference between a very good conductor and an inferior one. What was important was that the length should be as small as possible. If this was not attended to there was a risk that the conductor might do more harm than good. The chief obstacle to the passage of an impulsive current was not resistance but electric inertia. A long wire

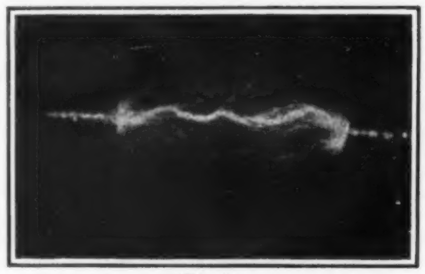

Fig. 1

Fig. 2

Fig. 3

resembled in this respect a long water pipe, in which it was difficult to suddenly start the fluid into motion. This reluctance of an impulsive current to follow a long path the lecturer illustrated by short-circuiting a spark gap by about 4 feet of wire. With a steady current the whole flow took place along the wire, while an impulsive current sparked across the gap.

Another way of using conductors was to arrange them so as to prevent the electric force over the area protected ever attaining so great an intensity as to permit of a flash coming down. In this case the conductors were provided with point terminals which, when the electric force reached a certain intensity, gave off a stream of electricity which formed a negative cloud above the building protected and below the positively charged base of the thundercloud. This stream of ionized gas reduced the electric force in the neighborhood, covering in effect the building below with a conductor which, as Faraday showed long ago, would be a perfect protector. In this connection the wind might prove of considerable importance by spreading and distributing the ionized layer over a large area. A conceivable way of protecting towns from damage by lightning would be to encircle them with appartus capable of producing ions. This would, on the approach of a storm, be set in action on the windward side of the town, and being carried over the latter by the wind, would act as a shield. This idea had not been as yet much developed. It had the advantage that the conductor was not put up to be shot at, but its function was to prevent the electric force rising to a dangerous pitch. To illustrate this effect the lecturer fitted a point to one of the electrodes of a large induction machine and showed that the point then produced a luminous brush, which was in essence the same as St. Elmo's fire, which in certain conditions streamed upward from pointed conductors into the air. He had himself seen it, at Cambridge, extending for many feet above the conductors of King's College Chapel. In the presence of this brush it was much more difficult to get sparks to pass between the terminals of the machine, and those that did pass were of not nearly so great an intensity as they would have been with the point replaced by a ball.

Leaving the subject of lighting, he would, the speaker proceeded, next consider other forms of discharge through gases. In the first place he would show how the appearance changed as the pressure was altered. With the gas at atmospheric pressure we got the familiar spark, which was the labortaory equivalent of lightning. On reducing the pressure, a peculir bluish appearance was first seen over the surface of the glass, and as the exhaustion proceeded the character of the discharge became more and more diffuse, and later on a dark space appeared in the neighborhood of the cathode and portions of the glass began to show a green phosphorescence, while the dark space grew larger and larger. Ultimately the discharge further differentiated. A fine velvety glow spread over the cathode, followed by a narrow, dark space, known, the speaker said, as Crookes's dark space; following this came a short luminous portion known as the negative glow, and then a dark space of varying length known as the Faraday dark space, while the remainder of the tube was filled with the so-called positive column of luminosity extending right up to the anode.

In another experiment, in which the cathode was perforated, the lecturer showed that a stream of particles, the so-called positive rays, passed through this hole and produced luminosity behind. This was quite different in color from the positive column and was not appreciably affected by a magnet, while as the lecturer showed, the cathode rays were very readily deflected. There was thus a great difference between the positive rays and the cathode rays.

It was natural, he continued, to assume that the potential difference required to produce a discharge should be greater the greater the distance between the terminals and the greater the pressure of the intervening gas. Within limits both these conclusions were correct, but experiment showed that there were some

*From a report in *Engineering*.

highly interesting exceptions. It was, in fact, extraordinarily difficult to get very short sparks. With a constant gas pressure there was, in fact, a certain length between terminals with which the discharge would pass more easily than with any other length of gap, whether longer or shorter. Similarly with a constant distance between terminals there was some particular gas pressure at which the discharge passed most easily. If this pressure were either raised or lowered from this optimum value the discharge got through with greater difficulty.

To illustrate the first peculiarity the lecturer employed the discharge tube represented in Fig. 4. Here the two terminals are brought in as indicated, the space between their opposing ends being only ½ mm. An alternative path for the discharge was provided round the spiral tube shown, its length being about ½ m. On coupling up the tube with an induction coil the lecturer showed that it was but rarely that a discharge passed across the ½-mm. gap, but selected in general the path 100 times as long.

In short, the speaker proceeded, the potential required to produce a spark between two terminals depended on the quantity of gas which intervened. If this were constant, it mattered not whether the pressure were low and the distance great or the pressure high and the distance short, the potential needed was constant so long as the quantity of intervening gas was constant. Hence a very short spark might correspond to a very small quantity of gas, and a discharge would be facilitated either by raising the pressure or increasing the distance between the terminals.

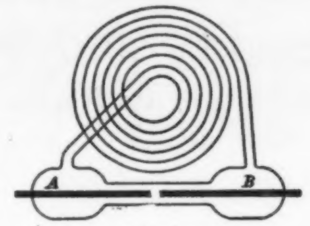

Fig. 4

To illustrate this the lecturer coupled up a discharge tube to an induction coil, and placed an ordinary spark gap in parallel with the discharge tube. At starting the pressure in the discharge tube was relatively high, and the whole of the discharge selected the spark gap for preference. The vacuum in the discharge tube was then improved by absorbing the gases in it by charcoal cooled with liquid air. As the exhaustion proceeded a point was reached at which the whole of the discharge passed through the tube and ceased across the spark gap, but on carrying the exhaustion still further the discharge in the tube ceased and the whole of the current passed again across the spark gap.

In a second experiment the barometric vacuum at the top of a long column of mercury was utilized as a discharge tube. A cathode floating on the mercury could be raised or lowered by raising the level of the mercury. The terminals of the discharge tube thus formed were coupled as before in parallel, with an alternative path for the spark. At starting the distance between the electrodes of the tube was great and all the discharge took the alternative path. With a certain length between electrodes, however, the discharge passed wholly through the tube and none across the alternative spark gap, but on still further raising the level of the mercury this gap came into action again and the discharge in the tube ceased.

In concluding his lecture the speaker exhibited a tube which had at one time belonged to De la Rue, and showed exceedingly well the striation often observed in the positive column of a discharge tube.

In this tube the positive column extended nearly from top to bottom and showed patches or layers alternately bright and dark, and nearly equally spaced throughout its whole length. Positive columns of this kind could, the speaker stated, be obtained of almost any length—in his own laboratory he had got them 50 feet or 60 feet long. The explanation of the striae had, he said, been the subject of a good deal of discussion, with which he proposed to deal in his next lecture.

[TO BE CONTINUED]

Correspondence

[The editors are not responsible for statements made in the correspondence column. Anonymous communications cannot be considered, but the names of correspondents will be withheld when so desired.]

Prejudice and the Principle of Relativity

To the Editor of the SCIENTIFIC AMERICAN SUPPLEMENT:

In the SCIENTIFIC AMERICAN SUPPLEMENT for June 30, 1917, there appeared an article entitled "The Principle of Relativity," by Alph. Berget, translated from the *Larousse Mensuel*. The writer of this article is evidently prejudiced against everything German. He directly and uncompromisingly attacks the Principle, and ridicules German science and scientists in general. His assertions are positive, and are supported by little or no line of scientific argument; there is no consideration of, or refutation of, arguments *for* the Principle; from first to last the fact is emphasized that the theory has been developed by Germans; it is strongly prejudiced throughout.

Now if there is one place in which prejudice and personal feelings must be altogether dispensed with, it is in the domain of Science. Science is universal, not the property of any one nation; all scientists have the common aim of unravelling the mysteries of the universe; all additions to knowledge, by whomsoever made, are welcome and valuable. All considerations must be fair and impartial. If M. Berget does not accept the Principle of Relativity, why doesn't he attack it in a decent, scientific manner? On the other hand, if he wishes to attack the Germans, why doesn't he choose some field other than that of Science in which to do so? Let us preserve the true Scientific attitude in spite of present world conditions.

That German science is nothing to be treated lightly should be realized from the accomplishments of Germany, and her wonderful industrial efficiency. However wrongly Germany may have applied her knowledge there is no reason for us to discount the value to be placed upon her monumental contributions to Science.

M. Berget's article having been called forth probably by prejudice, it is perhaps natural that his arguments are not particularly convincing when considered in a scientific way. He objects to the firm way[1] in which adherents of the Principle of Relativity uphold it; but he makes the same error himself. He says: "If certain savants regard this theory. . . . firmly established in science, there are numerous others, and no mean ones, who look upon it as a philosophic subtlety, and entirely reject it, basing this upon the inevitable necessity it involves of absolutely denying the existence of the ether." Now there *are* savants, "and no mean ones," *both* German and *non-German*, on *each* side: in a case of this kind, why should any one so positively assert either side to be right? The theory may be of little immediate consequence so far as every-day practical affairs are concerned, but its importance to pure science can hardly be overestimated;[2] even though it should have no physical truth, its cultivation is of the utmost importance to mathematics.[3]

[1]Somewhat exaggerated; See Cunningham, "The Principle of Relativity," *Nature*, 93:378-379, 1914.

[2]*Engineering*, 102:132-134, 1916, SCIENTIFIC AMERICAN SUPPLEMENT, Nov. 4, p. 291, 1916

[3]*Engineering*, 102:297-300, 1916.

M. Berget gives no account of the growth of the theory, of the recent modified, "generalized" form, or of the many instances where it so beautifully removes outstanding difficulties[4] and clears up thought. He dwells chiefly upon the unusualness of the conclusions to which the theory leads, and the changes in thought which it necessitates. At the outset he gathers together all the most startling conclusions, and impresses the reader with them; then he gives, briefly, and not in a clear, detailed manner, the things which led to the formulation of the Principle. But we cannot assert a thing to be wrong because it is strange to us. The scientist must frequently change his way of thinking as new discoveries arise. I think M. Berget somewhat exaggerates the extent of the revolution which the acceptance of the Principle necessitates, however. His paper is an example of the very *à priori* type of affirmation to which he objects.

He states that no one should have gone ahead with mathematical investigations just because it had not yet been possible to detect the motion of the earth relative to the ether; that is, we should never develop hypotheses and follow out their consequences so that we may test them out, and perhaps incidentally be led to new and fruitful lines of inquiry! The experimental evidence upon which the main lines of the Principle rest cannot be regarded too lightly, however.

The main and most extensive of M. Berget's arguments is that quoted above, having to do with the question of the ether. Now this is the old, original objection which has been urged upon us by everyone who ever opposed Relativity, and it has been successfully met a number of times.[5] The Principle of Relativity *does not deny* the existence of an objective ether.

If M. Berget accepts the electron theory of matter, why should he consider it absurd for a moving body to change its dimensions, and for energy to possess inertia?[6] If he is familiar with the recent work in the Quantum theory and related subjects, why should he be so opposed to the idea of an atomic-structure of energy, supposing the ether does happen to be non-existent?[7] Also, according to Berget, because we can conceive in our imagination of a velocity greater than that of light, then it must be possible for that velocity to exist.

The object of this communication is not to assert the truth of the Principle of Relativity (although personally I favor it), for there is evidence on both sides, but to point out the weakness of Berget's arguments; and to plead for the consideration of scientific questions in a scientific way, leaving prejudice aside.

EDGAR WOOLARD.

Boulder, Colorado.

[4]Especially the case of the motion of Mercury's perihelion: See *Nature*, 98:328-330, 1916; *The Astrophysical Journal* for May, 1917. For a presentation of both the "older" and the "generalized" relativity theories and an answer to objections, see Einstein, "Zum Relativitäts-Problem," *Scientia*, 15:337-348; 1914 This is reviewed in "*Revue Générale des Science*," 25:622-623, 1914.

[5]E. Cunningham, "Principle of Relativity," pp. 193-204, 1914; Cunningham, "The Principle of Relativity"; *Nature*, 93:408-410, 1914; E. Cunningham, "Relativity and the Electron Theory," pp. 87-94, 1915. *Nature*, 93:171, 1914. Lorentz, "Considérations Elémentaires Sur le Principe de Relativité," *Revue Générale des Sciences*, 25:179-186, 1914.

[6]See Comstock and Troland, "Nature of Matter and Electricity," 1917.

[7]*Scientific Monthly*, 4:509-534, June, 1917; *Science*, N.S., 4:5473, May 18, 1916.

True Greenheart is Not Poisonous

By C. D. Mell

THE wood of the true British Guiana greenheart employed so extensively in the English shipyards and in the construction of lock and dock gates, piers, etc., has frequently been stated to possess poisonous properties. Some authors not familiar, however, with the physical properties and chemical constituents of the wood, and who may never have seen or handled it, claim that blood poisoning has been known to result from abrasions of the skin caused by greenheart splinters. It is claimed that such cases have been reported among the men employed in shipyards in England where greenheart is used. Poisoning is said to result from slivers or splinters getting into the hands of workmen. Even inhaling the dust resulting from sawing, planing and scraping greenheart wood is believed by some to cause serious stomach and intestinal disorders.

Large quantities of greenheart timbers have been handled in this country and also in the Canal Zone and no deleterious results have been reported, nor has any injurious effects of this wood been observed in the country of its origin. In the mills and shops of this country where greenheart wood is used, it is a daily occurrence for men to get slivers into their hands and yet not a single case of illness has ever been reported. The laborers in the forests of British Guiana, who have been engaged in felling, squaring, hauling and rafting greenheart all their lives know nothing at all about the alleged poisonous properties of this wood. Yet, it seems that the men in the country where greenheart wood has been cut and exported for over 100 years, should have been the first to discover the fact, if the wood were poisonous.

Those who have looked into this subject are now fully convinced that true greenheart is not poisonous. Just how it came to be understood to be toxic in its properties was due perhaps to the fact that there is another wood from the same general region that is sometimes called greenheart or more often known as Surinam greenheart, because the bulk, if not all of it, came from Surinam, a Dutch colony in northern part of South America, bordering British Guiana, the home of true greenheart. The Surinam variety which is entirely different from the British Guiana kind, is known to be poisonous, and it was without doubt this wood that was occasionally mixed with logs of the true kind and may have caused ill effects.

Dr. Radlkofer informs us that the Surinam greenheart contains toxic properties that have been found useful as a fish poison, and a number of other chemists have isolated from Surinam greenheart wood an alkaloid called lapachol. Dr. Sam. C. Hooker, Brooklyn, N. Y., has made a very careful study of this alkaloid which he extracted from the pulverized wood of Surinam greenheart. He has recently examined two authentic samples of the true greenheart from British Guiana and lapachol was not present in either of them. Although a number of investigators claim that lapachol is found in true greenheart, it may be taken for granted that these chemists did not have authentic material of the true kind, but had the wood of Surinam kind. However, the fact that there have been no cases of poisoning from true greenheart reported in this country, nor in the source of origin is conclusive proof that the wood is not poisonous.

Heredity and Sex*

Mendelism and Some of Its Recent Developments

By Frank E. Lutz, Ph.D., Associate Curator, Invertibrate Zoölogy

The history of science is as full of episodes replete with "human interest" as is the history of nations. Not the least of these is the story of Gregor Mendel, a peasant, later a monk, and finally Abbot at Brünn, but now known not for his theology or his kindly deeds to his fellows, but for his patient and successful work in his avocation—the study of heredity. The principal material which he used in this study was the common pea, and his results were published in an obscure journal in 1865. Darwin knew of his work but failed to appreciate its significance. In fact, it remained unnoticed until eighteen years after Mendel had died when, independently but simultaneously, it was brought to our attention, together with important confirmations, by three noted botanists: De Vries, Correns, and Tschermak. Its rediscovery has not only given us a theory of heredity which has revolutionized the practical breeding of plants and lower animals, but also it has given a new impetus to the experimental study of evolution and, through the "eugenics" movement, bids fair to play an important part in the development of human society. It is fitting, therefore, that the American Museum should arrange exhibits illustrating the principles of Mendelism. In the Darwin hall of the American Museum, features of the Mendelian law of heredity are shown by means of peas and rats, while in the insect hall not only Mendelism, but also the later developments of Mendelism—its relation to the mechanism of the germ cell and to sex—are illustrated.

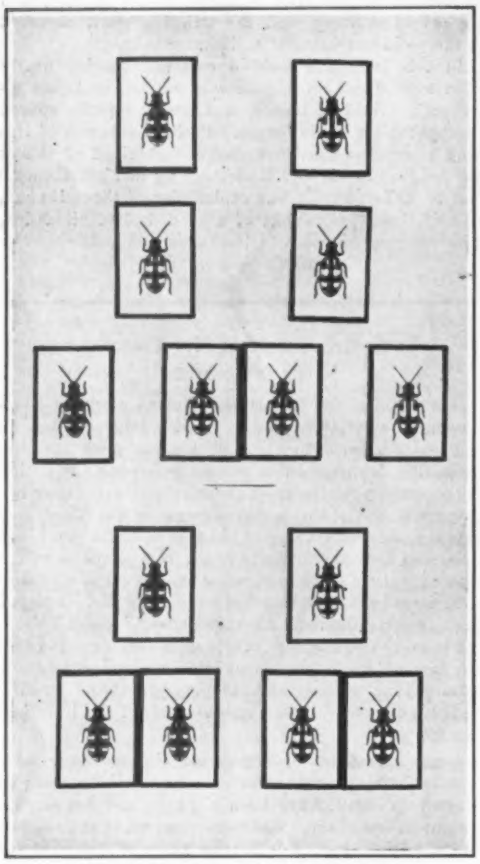

Fig. 1—Illustration of simple Mendelism

Inheritance of color pattern in the common asparagus bettle (*Crioceris asparagi*). The upper experiment shows the result of mating a beetle having spots small and separate with one having spots large and joined. The offspring are hybrids, unlike either parent, but if mated with one another half their offspring will be hybrids, one-fourth pure-blooded and like the original female ancestor, and one-fourth pure-blooded and like the original male ancestor. If one of these pure-blooded offspring now mates with a hybrid, the resulting offspring will be half hybrid and half pure-blooded, as shown in the lower experiment.

As an illustration of Medelism in its simplest form we may take the following: The commoner of the two beetles—both undesirable immigrants from Europe—which feed upon our asparagus is *Crioceris asparagi*. It is a small green creature with cream-colored markings. In some individuals these markings consist of three small spots on each wing cover; in other these spots are larger, and the two front ones on each side are joined. Now, if an asparagus beetle having the spots small and separate mates with one having the spots large and joined, the offspring (the "hybrids" or, as this generation is called, F_1) will have the spots large but not joined. If these hybrids mate, the next generation (F_2) will, in the long run, consist of one individual with spots small and separate to two with spots large and separate (hybrids) to one with spots large and joined. This is shown in the insect hall and in the figure 1. Half of the F_2 generation are hybrids, and if mated with similar hybrids will give offspring in these F_2 proportions, 1:2:1. The rest are pure. If spots-small-and-separate be mated with spots-small-and-separate all the offspring will have the spots small and separate, no matter what the previous ancestors were. Likewise spots-joined mated with spots-joined can give only spots-joined.

Although this case has not been as thoroughly studied as the others to be mentioned here, it is cited first because it shows clearly which are hybrids. In the others the law of dominance is so prominent that the simplicity of Mendelism is obscured. Let us analyze this case by means of symbols. We will let *S* stand for spots small and separate and *J* for spots joined. As every individual is made up of two parts, maternal and paternal, we will indicate individuals by two letters. The beetles with which we started are therefore *SS* and *JJ*. The former produces germ cells each one of which carries the factor *S*, and each of the germ cells of the latter carries *J*. United, these make a hybrid individual, *SJ*. Now the essential point is that a given germ cell can carry the factor for only one condition of a given character. Therefore hybrid asparagus beetles produce two kinds of germ cells, one bearing *S* and the other *J*. There are equal numbers of each kind. An *S* sperm has equal chances of fertilizing an *S* and a *J* egg, giving equal numbers of *SS* and *SJ* offspring. There are just as many *J* sperm, and they have equal chances of fertilizing an *S* and a *J* egg and therefore we should get a similar number of *SJ* and *JJ* offspring. The total would be one *SS* to two *SJ* to one *JJ*. "Q. E. D."

A further test consists in mating pure individuals with hybrids. *SS* produces only *S* germ cells, and *SJ* equal numbers of *S* and *J* germ cells. Therefore, there will be an equal number of the combinations, *SS* and *SJ*. See Fig. 1.

The ordinary "sour fly" or pomice fly (*Drosophila ampelophila*) has been used more than any other species of animal or plant in the experimental study of inheritance. The two examples used in the insect hall and shown in Fig. 3 are illustrations of simple Mendelism plus the law of dominance. This is a very slight complication and consists merely in the fact that when two characters are joined in the hybrid only one (the "dominant" one) is evident. The "recessive" character is there however, and half of the germ cells produced by such a hybrid bear only the recessive character. If a pomice fly having aborted wings of a certain kind be mated with a pure normal-winged fly, all the offspring (hybrids, or F_1) will have normal wings, for normal wing is dominant and aborted wing is recessive. If these hybrids be mated together we shall get in the F_2 generation, *one* pure normal-winged to *two* hybrid (but having normal wings), to *one* pure aborted-winged. More briefly, the ratio is *three* normal-winged to *one* aborted-winged. Although the eye cannot distinguish between the two kinds of normal-winged F_2, breeding shows that they exist in the proportions just mentioned. In the second illustration, normal body color is dominant and black is recessive.

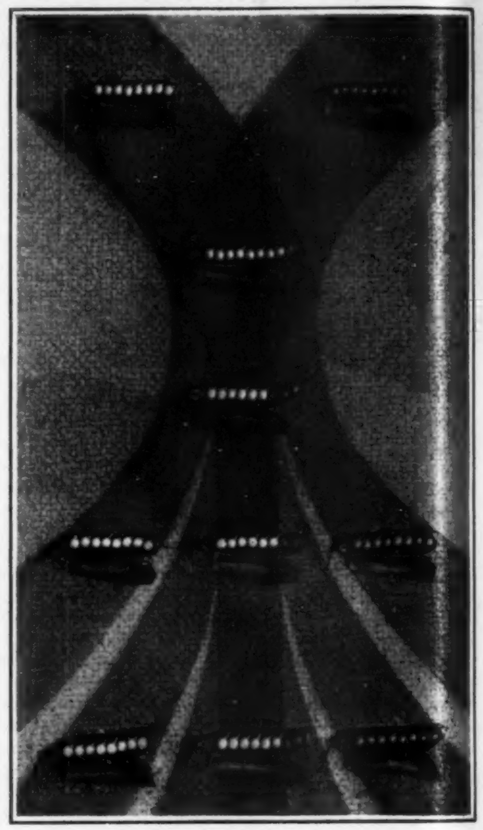

Fig. 2—Inheritance of color in peas

Mendel's classic experiments were made with the common garden pea (*Pisum sativum*). When peas of yellow seed color were crossed with those of green seed color, the peas of the resulting plants were all yellow. When these yellow peas were mated together the peas of the resulting plants were one-fourth pure yellow seed color, two-fourths yellow hybrids, and one-fourth pure green. Of these the pure yellows and greens bred true, the hybrids continuing to give half hybrids and half pures as before.

Mendel used peas in his own experiments, and in Fig. 2 is shown part of the exhibit in the Darwin hall illustrating these. The pair of characters concerned is yellow seed color (dominant) and green seed color (recessive). In order that this case may be understood in its relation to the zoölogical illustrations, it should be noted that seeds are really young next-generation plants. In this exhibit the fact is emphasized that the extracted dominants and recessives of F_2 and subsequent generations, *i.e.*, the pure offspring of hybrid parents, are really pure. If mated, each to its kind, they carry on their strain indefinitely.

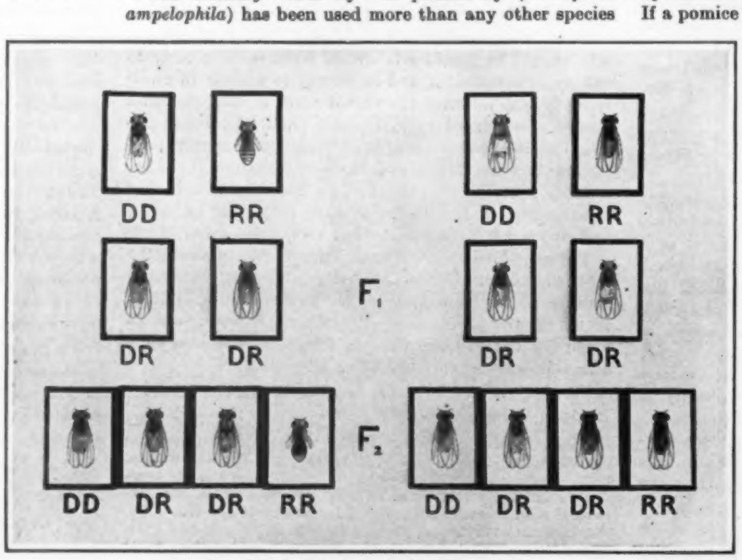

Fig. 3—The law of dominance

Inheritance of wing length (left) and of color (right) in the pomice fly. When two characters are joined in a hybrid, only one (the dominant one) is evident. Normal wing is dominant to aborted wing and light to dark color, so the offspring from a pure normal and an aborted-winged fly will all have normal wings. The recessive character is present however, in half the germ cells of each hybrid, and their mating will produce one pure dominant to two hybrids to one pure recessive, the pure dominant and both the hybrids having normal wings. Similarly in the color series.

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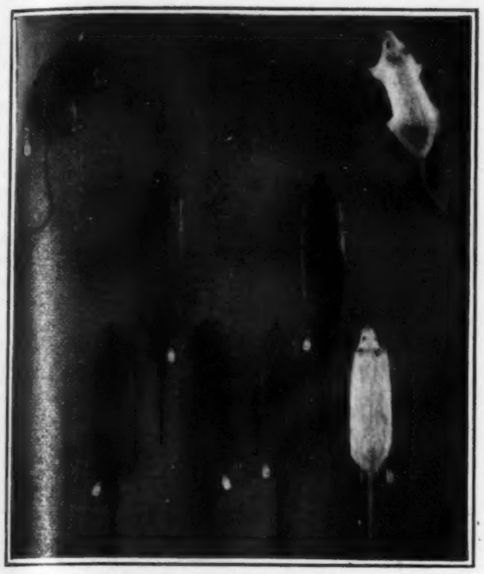


Fig. 4—Mendelism in rats

If a pure gray rat be mated with a white rat the offspring will all be gray, for gray is dominant and white is recessive. In the next generation there will be three grays to one white; the white and one of the grays are pure and will breed true; the other two grays are hybrids.

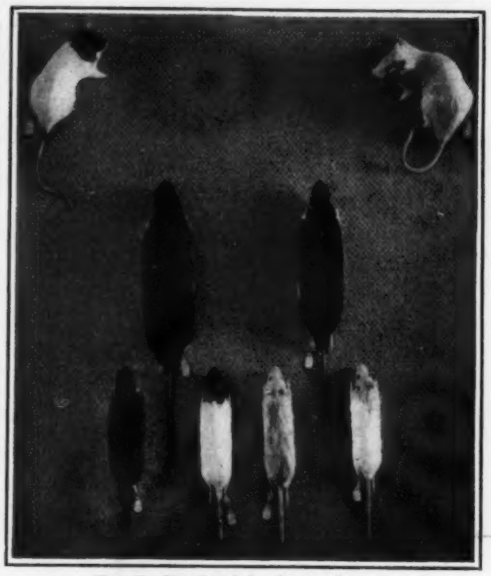


Fig. 5—Duplex inheritance in rats

The two pairs of characters here involved are black *versus* yellow, and self-colored *versus* hooded, black and self-colored being dominant, respectively, to yellow and hooded. The first-generation offspring are all gray hybrids, each with four different kinds of germ cells, which produce in the following generation four kinds of individuals, as in the case of the pomice flies. One only of each kind is shown.

Fig. 6—Inheritance of three pairs of characters

Where three pairs of characters are concerned in a cross there will be eight classes of individuals in the second generation of offspring. The pairs of characters concerned above are black and cream-colored, yellow and cream-colored, and self-colored and hooded (the condition in which all pigmentation is concentrated near the head). Black, yellow and self-colored are the dominants. The eight classes of offspring (of which only samples are shown) are: black-yellow-self (gray), black-yellow-hooded (white with gray hood), black-cream-self (black), black-cream-hooded (black hood), cream-yellow-self (yellow), cream-yellow-hooded (yellow hood), cream-cream-self (cream) and cream-cream-hooded (cream hood).

As illustrations of Mendelism in vertebrates, experiments with the wild, gray and domesticated "fancy" rats[1] are exhibited in the Darwin hall. If a pure gray rat be mated with a white rat the offspring will all be gray, for gray is dominant while white is recessive, and in the F_2 generation there will be three grays to one white (see Fig. 4). This white, however, will be pure. Suppose a breeder had only one white rat, but wished to establish a strain. He could mate it with a wild gray, and although the hybrids would all be gray, he could get *pure* white individuals either by mating the original white with one of its hybrid offspring, or by mating hybrids with hybrids. In the former case he would get 50 per cent hybrids to 50 per cent pure white (see the asparagus beetle illustration) and in the latter 75 per cent grays (one-third of them pure gray) to 25 per cent pure white.

Let us go a step further and consider what happens if there are two independent pairs of characters. In this connection compare Fig. 3 with Fig. 7. In Fig. 7 it is seen that one of the parents has aborted wings and dark body color while the other is normal with respect to each of these characters. Since light body color and normal wing are dominant, all of the F_1 generation are light and have normal wings. In the F_2 generation one-fourth of the offspring have aborted wings, one-fourth have dark body color, while three-fourths have long wings and three-fourths have light body color. However, there are four different combinations in the ratio of *nine* light-normal to *three* light-aborted to *three* dark-normal to *one* dark-aborted. Those acquainted with the laws of chance will see that this is the ratio to be expected if twelve light and four dark (3:1) be independent from, and combined in a random fashion, with twelve long and four aborted. The germinal analysis may be given as follows, L standing for light color, d for dark color, N for normal wing and a for aborted wing: The recessive condition of the characters is indicated by the small letters. The one parent, $LLNN$, produces germ cells which are all LN. The germ cells of the other parent, $ddaa$, are all da. Therefore the offspring will all be $LdNa$. These offspring, male and female, will each produce four kinds, (in equal numbers) of germ cells: LN, La, dN and da. Suppose the combinations of letters just given to be eggs, and combine them in a random fashion with the four kinds of sperm: LN, La, dN and da. LN sperm, fertilizing the various kinds of eggs, would produce equal numbers of $LLNN$, $LLNa$, $LdNN$ and $LdNa$ individuals. Writing out in like fashion the combinations

[1] The rats shown are largely from the important experiments of Professor W. E. Castle, of Harvard, who kindly outlined this portion of the exhibit. The rest of the rats were obtained from the New York Zoological Park through the courtesy of Mr. Ditmars.

for the other kinds of sperm and adding the results together, we find we have

$$1 \quad LLNN+2LLNa+2LdNN+4LdNa=9 \text{ light-normal},$$
$$1\ LLaa+2Ldaa= 3 \text{ light-aborted},$$
$$1\ ddNN+2\ ddNa= 3 \text{ dark-normal},$$
$$1\ ddaa= 1 \text{ dark-aborted}.$$

In the case of the rats (Fig. 5) only a sample of each class of F_2 individuals is shown. The ratio is nine black-self-colored to three black-hooded to three yellow-self-colored to one yellow-hooded, for black is dominant over yellow and self-colored over hooded.

There is, theoretically, no end to the number of pairs of characters which may be concerned in any one cross, but the principles are the same: a given germ cell carries but one of each pair, and where both

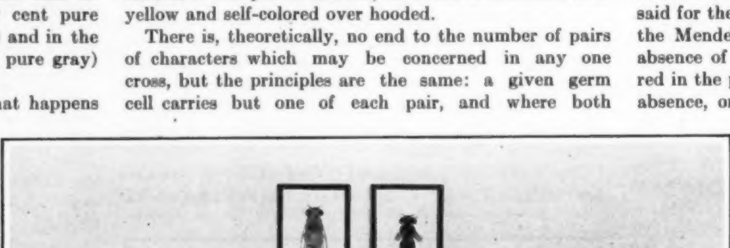


Fig. 7—Inheritance of two pairs of characters

Since light body color and normal wing are dominant characters, all of the first-generation offspring, from mating a light normal-winged with a dark aborted-winged individual, will be light with normal wings. These hybrids, however, will each produce in equal numbers, four different kinds of germ cells. In the third generation there will therefore be four different kinds of individuals, in the ratio of nine light-normal to three light-aborted to three dark-normal to one dark aborted.

members of a pair come together in the union of two germ cells to form an individual, one of the characters usually dominates over the other. If three pairs of characters are concerned there will be, typically, eight classes of offspring, in the F_2 generation. This is seen in the third exhibit (Fig. 6) illustrating inheritance of color and pattern in rats where, again, only samples of the various classes are shown. Frequently, as in the case of the rats, the breeder is able, by crossing known varieties, to get new or hitherto unknown varieties in F_2; that is, new combinations are made. The exhibit in the American Museum showing inheritance of flower color in sweet peas, is complicated by the fact that not only are there three pairs of characters, but also that color of any kind, that is any kind but white, can occur only when certain members of two of these pairs come together. One of the white parents had one of these characters and the other had the second; union by crossing gave colored offspring.

Before passing on to the explanation of what may be called the mechanism of Mendelism, a word should be said for the benefit of those who may have read or heard the Mendelian principles given in terms of presence or absence of characters. We may say that a fly's eye is red in the presence of the factor for red, and white in its absence, or we may speak of the pair of characters as red and white. It has seemed better to use the latter alternative here, but the presence-and-absence way of putting it works out well in certain cases and has given rise to some interesting speculations. Thus, Professor Bateson has suggested that all organic evolution has been brought about by the successive dropping out of characters. This seems hard to believe, but certainly the origin of many varieties, whose origin we think we have seen, can be neatly explained in that way.

In order to understand the mechanism of Mendelian inheritance it will be necessary to explain some of the details of cell structure. The bodies of all the higher animals and plants are made up of cells, which are frequently looked upon as units of body structure. The lowest animals and plants consist of but one of these cells. The germ cells, egg or sperm, are merely some of these cells split off from the main mass of body cells, and differentiated so that they may unite and form a new mass of body cells, the new individual. In some cases the egg cell can carry on this process without uniting with the sperm, but in the vast majority of cases among higher animals and plants such union is normally necessary. Within these cells are bodies called chromosomes, the name being given because they stain deeply when treated with certain reagents. The chromosomes have for some time been supposed to be the bearers of heritable characters, and this supposition has now become almost a certainty by reason of Mendelian studies, especially those with the pomice fly, *Drosophila ampelophila*. We are, as yet, in the dark concerning the exact method by which these characters are transmitted, so that "bearers of heritable characters" is in great part a figure of speech, but, at any rate, these characters are somehow bound up with special chromosomes.

Most, and probably all, organisms have a definite number of these chromosomes, although the number is

not always the same in both sexes. In the pomice fly the number is the same (eight) in each sex, but one of the chromosomes (the "Y") of the male seems to carry maleness and not, as far as is known, any other character. When it is present the individual is a male. It is, however, paired in the body cells of the males with a chromosome which does carry factors for certain body characters, and this other chromosome may be called X. In each of the female body cells there is a pair of these X chromosomes but no Y. When a body cell destined to become a germ cell differentiates, the result of the rather complicated process may be stated simply by saying that it breaks in two, making two nearly similar cells. In the case of the male, the Y chromosome goes to one half, *i. e.*, to one sperm, and the X chromosome to the other. Each egg has an X chromosome. If a sperm having a Y chromosome enters an egg, the union will have one X and one Y and the resulting individual will be a male. However, if a sperm having an X chromosome enters an egg, the union will have X paired with X; there will be no Y and the resulting individual will be a female. Since the chances are equal that an egg will be fertilized by a Y-bearing sperm or by an X-bearing sperm the determination of sex is a random matter; it depends upon which sperm enters and not at all upon the mother; and the number of each sex will, in the long run, be equal. All this is, of course, subject to amendment by further investigation, and too sweeping generalizations should not be made, but it, or a similar relation, seems to hold for other strictly bisexual animals and it is the only explanation for the following, among other, facts:

A few pomice flies were found having white eyes instead of red. This white condition is recessive to red but in inheritance the proportions are not those of simple Mendelism. In what has gone before nothing was said about sex, because characters which have been previously mentioned occur without regard to it. This particular eye color however, is one of a number of characters which are "sex linked." If a white-eyed male be mated with a pure red-eyed female (see Fig. 8), all the offspring, both male and female, will have red eyes. If these offspring be mated with one another, all the females of the next generation will have red eyes, but half of the males will have white eyes and only half will have red eyes. On the other hand, if a red-eyed male be mated with a white-eyed female (see Fig. 9), all the male offspring will have white eyes and all the female offspring will have red eyes. This is what has been called "criss-cross" inheritance—the sons being like their mother and the daughters like their father. If these offspring be mated with one another, half of the male and half of the female offspring will have white eyes, the remainder having red eyes.

The explanation is as follows: This pair of characters, red eye *versus* white eye, is associated with the X, or sex, chromosome. In the first case mentioned the female was pure with respect to this eye-color character; that is, both of the X chromosomes carried the factor for red eye color (see Fig. 8). The male, since it showed the recessive character, must have been pure with respect to white eye color and, furthermore, all males are necessarily pure with respect to this particular pair of eye colors, and also with respect to all other sex-linked characters, since they have but one X chromosome, and since that chromosome, like any other, can bear the factor for only one of a pair of characters. All of the eggs, in this mating, carried the factor for red eye color. Half of the sperm carried the factor for white eye color and the other half had no factor concerned with this pair of characters. If a sperm bearing the factor for white eye color united with an egg, the offspring would be a hybrid since it contained factors for both eye colors, but, since red is dominant over white in this case, this individual would show the red color. It would also be a female, since the union which produced it was with a sperm having an X chromosome. If a sperm not bearing the X chromosome (that is, one with the Y) united with one of the eggs, all of which bore the factor for red eye color, the result would be a male pure with respect to red eye color, since the only factor concerned with this pair of characters came with the egg and was red. In other words, all the females of this generation had red eyes and were hybrids with respect to eye color, while all the males had red eyes and were pure with respect to eye color. Half of the eggs which go to produce the next generation bear the factor for red eye color, and the other half bear the factor for white eye color. Half of the sperm have X chromosomes bearing the factor for red eye color, and the other half have no X chromosomes, and thus have no influence upon eye color. Taking up the first class of sperm, namely, those bearing the X chromosomes: they will, when uniting with an egg, produce female individuals and, since half of the eyes have the factor for red while the other half have the factor for white, half of the resulting females will be pure red, while the other half will be hybrid, but will have red eyes because red is

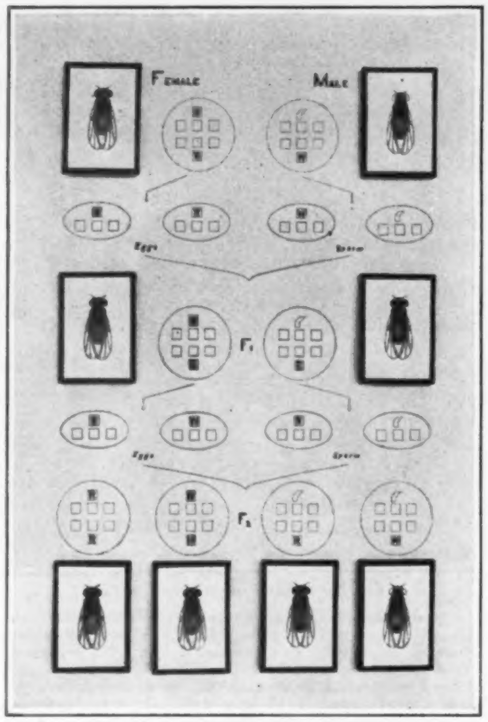


Fig. 8—Sex-Linked Inheritance

White eye color in the pomice fly is one of a number of characters which are sex-linked. The diagram represents the chromosomes of the pomice fly, circles referring to body cells and ovals to germ cells. The sex chromosomes are shown above and below the ordinary chromosomes (see text), the factor for eye color which each one carries being indicated by an initial. The odd-shaped figure is the "Y" chromosome. When this is present the individual is a male.

dominant over white. In other words, all of the females of this generation show red eyes. When the sperm lacking X chromosomes unites with the eggs, half of which have the factor for red in their X chromosomes and the other half white, the result will be males, half of which will be pure red and the other half of which will be pure white. This gives us the result stated above; namely, all the females and half of the males red-eyed while the other half of the males are white-eyed. This case may perhaps be more readily understood by reference to Fig. 8, and Fig. 9 shows the details of the second case mentioned above, which involves what is known as "criss-cross" inheritance.

The relatively complicated "sex-linked" inheritance just explained became simple when the explanation was

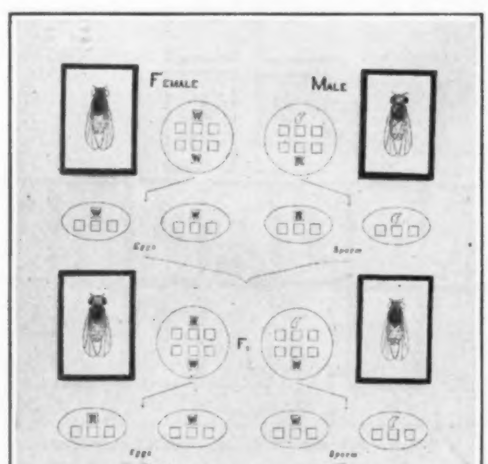


Fig. 9—Criss-cross sex-linked inheritance

If a red-eyed male be mated with a white-eyed female, all the male offspring will have white eyes and all the female offspring red eyes; if these be mated with one another, half of the male and half of the female offspring will have white eyes, the remainder having red eyes.

found, and comes near to demonstrating that there is a relation between heritable characters and chromosomes. It would probably be carrying scientific scepticism too far to continue doubting that it is a causal relation. Ordinary Mendelian characters, that is, those which come out in F_2 in the 3:1 ratio, are related to or borne by the ordinary chromosomes, that is, those chromosomes which are alike and paired in each sex. The interested reader may make diagrams, similar to the ones given here, which will show the mechanism graphically. Now that we think we know where the something which transmits a given character lies in the germ cell, we begin to wonder harder than ever what that something is and how it does it. A number of big steps have been taken in the explanation of heredity and, although the goal is still far ahead, by looking back over the ground already covered we are encouraged to believe that it will finally be reached.

Electric and Hydraulic Transmission

Dealing with the subject of Hydraulic Transmission before the Institution of Automobile Engineers, London, Mr. F. Leigh Martineau said that "an apt comparison could be drawn between a hydraulic transmission and an electric transmission, as the two are similar in many respects. In an electric transmission the essential elements are: (1) The prime mover driving—(2) a generator; (3) a conductor system; (4) an electric motor operating—(5) the driving wheels. So in a hydraulic transmission these elements become:—(1) The prime mover driving—(2) a pump; (3) a pipe system; (4) a hydraulic motor operating—(5) the driving wheels. Their operations may be compared as follows: In the former, the prime mover drives the generator and converts its energy into "electric energy," which is conveyed by the conductor system to the electric motor, where it is reconverted for use at the driving wheels. In the latter case, the prime mover drives the pump and converts its energy into "pressure energy," which is conveyed by the pipe system to the motor, where it is reconverted for use at the road wheels. The claims in favor of electric transmission, however, are, that it is usually more economical, is easily applied at considerable distances from the source of energy supply, and requires considerably less attention than the hydraulic system in regard to upkeep.

However, Mr. Martineau's main interest was with the different types of hydraulic transmission in manufacturing processes of one kind or another. For this purpose the author held that the radial rotating plunger and the axial rotating plunger types of pumps were best suited, because, he declared, experience seemed to show "that for hydraulic transmission to be effective in practice it is necessary to run at high pressure and with small volume, so that the hydraulic losses may be as low as possible, and the oil by this means kept cool; this will increase the mechanical and slip losses, but the net result will be better, and such heating as occurs will be as much in metal of high conductivity as in oil of low conductivity." While with the radial rotary pumps good material and workmanship are essential, they present the advantage of being easily and cheaply produced in quantities, having very few parts, and most of the work on them being cylindrical, can be carried out by grinding.

As regards hydraulic transmission for automobiles, especially of the heavy tractor and other heavy vehicle types, Mr. Martineau has great hopes for the future. He does not consider that it need be heavier than gear transmission, for "it must be remembered that as a rule the fly-wheel clutch, gear box, and countershaft brake can be totally eliminated from the chassis and replaced by two units in one case, which is mostly revolving weight, and will perform all the functions of the parts mentioned, with the added advantages of being able to make use of the whole of the engine power all the time during acceleration, using all the engine power at its most efficient speed on inclines, and having at command an absolutely steady retarding effect which converts surplus energy into heat without causing wear. By using high quality materials and good design the weight of such a transmission can be the same as its equivalent gear box, etc." He thought that there should not be any increase of cost. The question of complication had to be considered from the point of view of the manufacturer and the user. "The manufacturer," he argued, "will have fewer unlike parts to produce, but will have to make more like parts per car; this would seem to indicate simplicity and not complication from his point of view. The user has less to look after and no adjustments or adjustable parts to look after, but he has to keep the case full of oil to a certain mark, and that is all; this does not appear to show complication from his point of view."—*The Practical Engineer.*

Gravitational Attractions*

By F. H. Loring

THE mutual attraction of matter either within its self-same mass or across intervening space which as far as can be found possesses no corresponding magnetic field, nor contains any other linking device, has been a profound mystery. The law of attraction is well known, but no connecting mechanism has been discovered.

The general fact of gravitation is simple, namely, "that between every pair of material particles there exists an attractive force which is proportional to the product of the masses of the two particles, and to the reciprocal of the square of the distance between them" (Risteen). Put in another way, it may be stated that all material bodies attract each other, and taking for convenience, pairs, the attractive force is proportional to the product of their masses and the reciprocal of the squares of their distances apart, the bodies being considered as shrunk to points when taking the distances between them.

In some respects magnetic attraction seems intimately related to gravitational attraction, and it is suggested that both are of common origin.

Starting with magnetic phenomena, opinion differs as to the physical interpretation of magnetism, one school of thought holding that since a magnetic field has both *direction* and *intensity* it can be truthfully represented by actual lines of magnetic force, the number taken representing the intensity.

The other school considers this idea too descriptive, and they say it is only the mathematical relationships which are known, and these do not themselves justify such a physical interpretation.

Magnetic phenomena, however, give color to the physical theory in question, and it is largely held that the line of force conception is so near to the actual truth that a literal interpretation is possible without leading to error in practice.

The magnetic field round a current-bearing conductor may be represented in the usual manner by concentric encircling lines, and the fact that these lines are influenced by neighboring lines of another like current-bearing conductor in such manner that they become mutually distorted leads to the belief that, however much two or more fields encroach on each other, the lines are crowded togther but not necessarily annihilated; yet, in effect they neutralize each other where their directions do not coincide, that is to say, where they are superposed while in opposition.

A circular group of current-bearing conductors (arranged in squirrel-cage fashion) may be so far apart as not to give rise to any appreciable distortion of the magnetic lines, and therefore involve no consequent neutralization—this latter term to be taken to have a particular meaning presently.

In order to study the behavior of the lines of force, the wires may be slowly moved together, so as to consolidate them eventually into a solid round rod, the field gradually changing *until complete radial neutralization takes place:* wherein lies a new or extended conception of the character of magnetic lines of force when it is understood that the term *neutralization* as here used may be defined as a phenomenon resembling the neutralization of an acid with an alkali, in that the components are not annihilated. This will be better understood from what follows.

Consider the wires thus consolidated into a homogeneous rod and consequently the neutralization being along radial lines extending from the center of the rod, whilst at the turning points or places the lines may form *resultant* ones. It is to be noted that the turning places widen in proportion to the distance taken from the conductor. The original wires may be considered as shrunk to atomic or molecular thinness when tracing the effect back to its elemental origin.

The circular lines taken external to the conductor are therefore supposed to be made up from the radial loops, the former being resultant lines as shown by the accompanying diagram.

If the lines of force are not annihilated, then either two or more forces occupy the same place, or the opposing lines are closly packed together. Force is not a *thing* in the accepted material sense, but a magnetic field has such characteristics as to lead one to suspect that whatever the field may be, there is an intensity of action which behaves to material bodies of a certain kind (a moving mass of copper for example) as if there was a medium present. In all probability the action of forces may be regarded as perfectly superposable without individual destruction, and thus they become differentiated from matter, though forming in a sense a part thereof, just as the momentum of a body is bound up with it, but can have no value until the body is moved.

In the above case there is a certain condition of affairs assumed that resembles gravitational attraction, in that the neutralized lines of force disappear to all intents and purposes; and, if a plastic iron tube or ring were arranged to surround a current-bearing wire, being placed concentrically to it with an annular intervening space, the iron would be expected to contract on the wire when the circuit was established, just as if the wire attracted it gravitationally. This, of course, is a purely hypothetical case, as the iron would have to retain its magnetic property and yet remain pliable.

The hypothetical iron would be the seat of a strong magnetic flux (assuming considerable current passing through the central conductor), and according to the usual conception it would be said that the closed lines in the iron were like stretched elastic bands and tended to contract upon themselves and thus force the plastic iron to collapse or extend itself to the wire. If the iron accommodates or induces a greater total flux in a given position, it will retain that position, but if in a new position it will accommodate or induce more lines, the iron will endeavor to take up such a position.

The movement of the plastic iron toward the wire is a case of action at a distance due to the magnetism yet without any intervening cross-magnetic field that can be detected as such. It would appear that the wire was attracting the iron in a gravitational manner, since no extraneous radial magnetic field would be discernible.

If now the principle of neutralized lines in the chemical sense (see above) be accepted, then these lines are the ones which are in reality causing the iron to move toward the wire, unless the lining-up of the molecules or atoms in the iron contributes overwhelmingly toward the elastic-band effect: due to an increased number of lines, the permeability of the iron being very high.

Whatever action takes place, the idea of neutralized lines affords a second-order effect, which might provide a means of explaining or in some way elucidating gravitational attraction without introducing any new basic conception other than that of the magnetic field interpreted in an extended way.

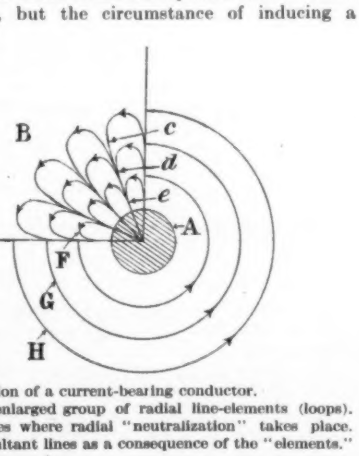
Accordingly, gravitational attraction might be taken as a sort of superposed magnetic effect, the intervening lines of magnetism being neutralized but still there and functioning as elastic bands or filaments interlinking or uniting all matter.

It is to be further noted that probably the plastic iron will be attracted wireward regardless of the direction of the central current, thus leading to the supposition that attraction would follow even if the current were to flow simultaneously in opposite directions. That the attraction would be exceedingly small in such a case seems probable, since opposing currents in side-by-side conductors, though in a sense equivalent to a single-direction current of equal total amperage, would not induce any molecular or atomic rearrangement in the iron, consequently there would be no organized flux therein.

Since therefore, direction plays no absolute part in the secondary, or second-order effect, a linear or organized current would not be necessary, and it seems probable that molecular or atomic currents would meet the case, these currents taken collectively being heterogeneous.

The weakness of the gravitational field in comparison with a magnetic field supports the idea that the neutralization effect reduces the magnetic effect to one of a second order, and therefore great masses are necessarily involved in obtaining appreciable attraction.

This argument, or rather the extended interpretation of well-known phenomena, leads to the supposition that lines of magnetic force are never destroyed, but only brought into requisition by the artifice of the experimenter, or by the device of the engineer. Moreover, the second-order effect would be expected rather than a first-order one, but the circumstance of inducing a



A = Section of a current-bearing conductor.
B = An enlarged group of radial line-elements (loops).
c, d, and e = Places where radial "neutralization" takes place.
F, G, and H = Resultant lines as a consequence of the "elements."

magnetic flux in a ring of iron or steel would not perceptibly lessen its weight. The mass of the earth is so great compared with, say, a magnetized ring, that the former would be expected to contribute the effective lines in proportion to its mass; consequently, whatever contribution there may be from the magnet it would be negligible by comparison, and it would probably be impossible to detect any difference in weight even by means of a sensitive balance. It is assumed that organizing the lines of the magnet would prevent them functioning in a gravitational capacity.

It might be possible to devise an experiment somewhat along the lines of Dr. Shaw's experiment (a brief mention of the latest contribution by Shaw and Haynes, is given in the *Chemical News*, cxv., p. 116), which should, according to this hypothesis, show a difference in attraction when a ring of iron or steel is highly magnetized.

There are several interesting developments which are not in conflict with the hypothesis. The shielding action of iron toward magnetic lines is evidently due to the organized flux therein, and such a flux is differentiable from the resultant lines that may be developed in space or practically non-magnetic media, the former not being resultant lines in the same sense though inducible by the latter. The iron-flux, for example, is a molecular or atomic phenomenon of self-contained origin within the iron. The neutralized lines, moreover, pass, for instance, through iron the same as through brass, and this property is demanded of any lines that function in a gravitational capacity. Electrostatic lines are, by the way, ruled out of consideration, as a basis for gravitational attraction, because they are stopped by metallic surfaces.

According to this hypothesis, therefore, *gravitational attraction might be defined as a second-order magnetic effect whereby the lines of magnetic force are neutralized so far as any manifestation in the gravitational field is concerned, but these lines being in the field or in intervening space and having an origin in the atomic currents in the masses of matter involved, proportionate to their conjoint masses, give rise to a binding attraction by virtue of the inherent property of magnetic lines to act as stretched elastic bands.* This leads to the magnetic field round a conductor being made up of radial elements substantially as illustrated by the diagram.

That the lines have an origin in the atomic currents may be more apparent than real, since the neutralized lines of force may represent a property of space, the atoms serving as anchoring media.

Faraday, to whom we owe the conception of lines of force, thought that all space contained such lines, and we know that the magnetic field of the earth is an example of magnetic lines on a large scale. Faraday also had in mind *electrostatic* lines which are not under consideration except in so far as a moving charge gives rise to a magnetic field (Rowland).

In an attempt to visualize these lines of force in their bewildering maze of complexity the mind reels at the thought, but this idea may be a comparable counterpart to the marvel of the electric-atomic structure of matter itself. The peopling of all solid, liquid, and gaseous bodies with live electrons is difficult to comprehend. Each atom is, in fact, a miniature planetary system, and the revolving negative electrons give in effect the atomic currents mentioned above. The number of such systems in the smallest speck of dust discernible, and that this dust particle will fall to earth by reason of that which is linked up to it and extending far beyond its confines, are equally difficult of realization.

The whole conception rests upon an hypothesis of *force lines*, the extent and nature of which involves thinking of them in terms distinct from those of matter, very much as the *modern* principle of relativity becomes an extension of thought beyond that of *classical* relativity. For an interesting phase of the relativity philosophy Minkowski's *world lines* become of interst. See Silberstein's "Theory of Relativity" (Macmillan, 1914), pp. 129-131. Quite apart from the relativity conception, a thing is not complete from the point of view of this hypothesis if specified in terms of three dimensions, because it is linked up with other things, hence a fourth dimension seems necessary: one implying *volume extension*. A charming paper on the "Fourth Dimension," by Eleanor Beatrice Harvey, (*Trans. Rochdale Literary and Scientific Soc.*, 1912, xl., 5-17), though not giving exactly this idea is highly suggestive.

*The *Chemical News*.

Rubber Exports from Straits Settlements

A cable received by the Malay States Information Agency from the Colonial Secretary at Singapore states that the export of plantation rubber from the Straits Settlements ports for the month of June last amounted to 3,836 long tons, as compared with 3,274 tons in May, making the total for the six months 23,612 tons, as against 15,609 tons in the corresponding period of 1915, says the *London Chamber of Commerce Journal*. These figures include trans-shipments of rubber from various places in the neighborhood of the Straits Settlements, such as Borneo, Java, Sumatra and the non-federated Malay States, as well as rubber actually exported from the colony, but do not include rubber exports from the Federated Malay States.

The Unipolar Dynamo and Its Future

A Simple and Efficient Type Possessing Great Possibilities

By Louis B. Lawrence, E.E.

WHENEVER the word "dynamo" is mentioned, the attentive listener pictures a complicated machine having several poles, and a big iron armature around which an almost infinite number of turns of copper wire are coiled snake-like, and on one end of which a huge copper commutator is affixed. On this commutator, a number of brushes bear gently, collecting the energy set up in the armature and sending it to the distributing wires and cables.

Very few among my readers are aware of the fact that there is another type of dynamo, simple and efficient, and which although it has really been the ancestor of the immortal Gramme direct current generator, and although it is suitable, as yet, only for some special uses, will eventually come unto its own, and displace its huge descendent. This type is known under the name of *unipolar dynamo*, or, as it has been suggested, no dynamo having less than two poles, *homopolar dynamo*.

In the Gramme machine, or in other types of modern dynamos which are, after all, nothing but modifications and improvements upon the Gramme construction, the current set up in the armature windings is alternating, because the conductors, as they revolve, pass under a north magnetic pole, and then under a south pole, and in order to obtain direct current in the external circuit, some means must be resorted to in order to reverse the connections every time the current reverses in the armature windings; the commutator was devised to fulfill that duty. But, if the machine is arranged so that the armature conductors will always cut across the magnetic field in the same direction, the currents flowing in the armature windings will be direct and no commutator will be required. Such was the apparatus called "Barlow wheel" and illustrated by Fig. 1. It consists essentially of a copper disk, mounted so that it projects between the poles of a horseshoe magnet, and dips in mercury. If the wheel is rotated, it cuts across the lines of force passing from pole to pole, and an electro motive force will be set up in the disk, which, according to the laws of induced currents, will be exerted along one of the radii of the disk. If contact is made to the shaft, and also to the mercury in which the wheel is dipping, a complete unipolar generator will be realized, and the current obtained will be a direct continuous current. The disk is, electrically speaking, equal to a great number of radial conductors coupled in parallel, so that the electromotive force generated is low, but, on the other hand, the large cross-section of the disk allows enormous currents to flow, thus making the machine an ideal one for electrolytic purposes.

From the laws ruling the setting up of an electromotive force in a conductor cutting across a magnetic field, we know that the conductor must cut 100,000,000 lines of force per second, and from that, and also the fact that the disk of a unipolar dynamo is equivalent to only one conductor, it is evident that the magnet and the disk must be quite large, or that the disk must be revolved at a very high speed if the machine is to deliver current at a high potential.

The advent of the steam turbine, with its high efficiency and high rotative speed, has reopened the field for the unipolar generator; for, on account of the slow speed of the prime movers that could be depended on to run dynamo-electric generators, the Gramme construction had to be adopted, which procures a great number of conductors connected in series, so that with a small magnetic field, and at a low speed, high potentials are set up in the armature. But, when a Gramme generator has to be designed for direct coupling to a steam turbine, the problem is by no means a simple one, if efficiency is sought; for on account of the very sharp reversals of current in the windings, the losses due to hysteresis, eddy currents, etc., are very large.

With the unipolar generator, on the other hand, speed is needed, and there being no reversals of either current or magnetism in the armature, a great many losses are avoided, making the combination a highly efficient one.

There is, however, an inconvenience to the direct connecting of the steam turbine with the unipolar generator, and that is the difficulty of mounting sliding contacts that will operate properly at the enormous peripheral speeds of the steam turbine, which, in some cases reaches 80,000 feet per minute, De Laval turbines being considered. In connection with this, I must draw the attention of the reader to the fact that commutator trouble and sparking is always liable to happen with ordinary turbo-generators, while no sparking can occur with the unipolar, the brushes gliding on a perfectly continuous and smooth surface, the periphery of the disk.

Although the construction of the unipolar generator is made more difficult by using several disks, still, when the voltage of the machine must be high, the dimensions reduced, and the speed of the prime mover is not excessive, two or more disk-armatures can be mounted in series, and connected by means of sliding contacts, for it is evident that should the conductors connecting the disks in series be rotated with them across the magnetic field, an electromotive force equal and opposite to that one induced in the disk would be set up in said conductors, and the machine would deliver the same voltage as if it had only one disk. Fig. 2 shows the principal parts of the construction of modern unipolar generators. The magnet of the Barlow wheel is replaced by a powerful electromagnet, able to set up a density of about 95,000 lines of force per square inch through the air gap on either side of the disk armature. The drop of mercury has given way to a set of copper or carbon brushes, and the thin copper disk has become a thick steel disk accurately mounted between the poles of the electromagnet. The short arrows in this figure indicate the paths followed by the currents when the machine is in operation, while the dotted lines show the direction of the magnetic lines of force of the electromagnet, and the short curved arrows coiling around the shaft give the direction of rotation.

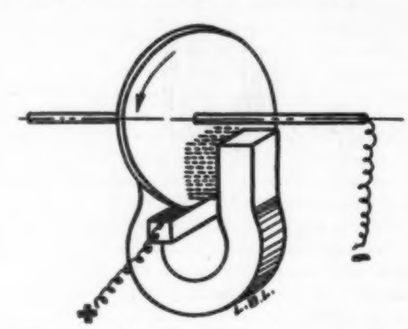


Fig. 1—Barlow wheel acting as a generator

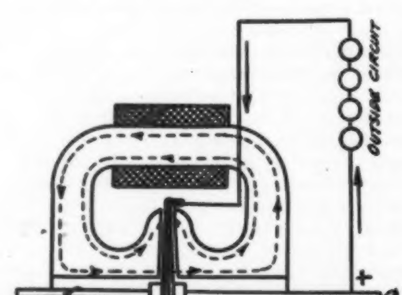


Fig. 2—Single disk Unipolar generator

The design of a unipolar generator, as a whole, is quite a simple proposition, the voltage to be generated and mechanical strength being the only factors that have to be considered, for stiffness of the disk alone compel the designer to give it a cross-section large enough to carry quite a large amount of current. For example, with a single disk machine, required to give 50 volts at the terminals at 20,000 r.p.m., a steel disk armature, 16 inches in diameter, cutting across a magnetic field of a density of 95,000 lines of force per square inch would be sufficient, and for that speed and diameter, a disk not less than ¼-inch minimum thickness is required to avoid side bending. Such a disk will safely carry 400 amperes, if eight sliding contacts are provided at its periphery, thus making a machine with a normal output of 20 k.w.

I have already said that the losses of energy in the unipolar generator are quite low. As a matter of fact most of the causes for loss that are met with in the construction of the standard dynamo are done away with in the unipolar, for, where could hysteresis happen? There are no reversals of magnetism; where could eddy currents be a loss? There is no iron armature that can develop them. The air gap is also reduced to a very minimum, for the steel disk armature can be mounted and faced with the utmost accuracy. Magnetic leakage is so small that it can be put aside in the practical design, the lines of force having the easiest path squarely through the disk. At the same time, overload does no harm to the unipolar; there is no delicate, heat fearing, cotton-shellac insulation that is destroyed by heat; all the insulating material needed can be a compound of asbestos, which would allow the conductors to get red-hot, and still keep on insulating them properly. The capacity of the prime mover is the only stop to the overload of a unipolar generator.

Comparison between the unipolar and the multipolar generators is not to the advantage of the latter, and had the high speed steam turbine been developed earlier, there is no doubt but that the unipolar would now be extensively used wherever direct current is required.

Slowly, but surely, direct current is replaced by alternating current in most lines of industry, and it can easily be surmised that it will ultimately be restricted to electrolytic or electrochemical processes, requiring but a low voltage and enormous amperage, and there lies the future of the unipolar, which, by its efficiency and simplicity will push aside every other type of generator.

The tables below furnish some idea of the relations of sizes, voltages, and outputs of the most efficient types of unipolar dynamos, the data having been collected by the writer on European machines, the unipolar generator being well used there in the electrolytic industries.

LOW SPEED UNIPOLAR GENERATORS

PERIPHERAL SPEED BETWEEN 15,000 AND 25,000 FEET PER MINUTE
AIR-GAP DENSITY, 95,000 LINES PER SQUARE INCH

RATING K.W.	NORMAL VOLTS	NORMAL AMPS.	NO. OF DISKS	LENGTH OF AIR-GAP	DIAM. OF DISK	PERIPHERAL SPEED	R.P.M.
10	20	500	1	3/64"	30"	15,700	2,000
30	50	600	2	3/64"	32"	18,200	2,200
100	100	1000	2	1/16"	48"	23,800	1,900

HIGH SPEED UNIPOLAR GENERATORS

PERIPHERAL SPEED BETWEEN 40,000 AND 60,000 FEET PER MINUTE
AIR-GAP DENSITY, 95,000 LINES PER SQUARE INCH

RATING K.W.	NORMAL VOLTS	NORMAL AMPS.	NO. OF DISKS	LENGTH OF AIR-GAP	DIAM. OF DISK	PERIPHERAL SPEED	R.P.M.
10	25	400	1	1/32"	16"	41,900	10,000
20	50	400	2	1/32"	16"	41,900	10,000
30	50	600	1	3/64"	21"	56,100	10,100
100	100	1000	1	1/16"	48"	46,500	3,700
200	200	1000	2	1/16"	48"	46,500	3,700
450	300	1500	2	3/32"	60"	55,000	3,500
750	500	1500	4	3/32"	60"	45,500	2,900

A few queer types of unipolar generators have been built in which the armature is in the form of a drum or cylinder, but they are not practical for high speed, the disk alone being susceptible of being accurately machined and balanced, thus eliminating vibrations and jerks.

The unipolar turbo generator presents as a whole the most compact and efficient direct current equipment known, and in this day of efficiency it has an assigned place which it doubtless can fill to advantage.

Mechanical Testing of Cast Iron*

New Device to Determine Hardness

THE testing of cast iron mechanically was discussed by F. J. Cook before the South Staffordshire Iron and Steel Institute (British) at a recent meeting. The two principal points touched on in the paper, "Mechanical Tests of Cast Iron," were tests usually called for by engineers' specifications and those adopted as a guide to efficient working in the foundry.

Anyone looking into the tests usually included in engineers' specifications, who is at all familiar with the metallurgy of cast iron, said the author, cannot fail to be struck with the fact that they are so carelessly framed as to be of no practical value. The tests called for by specifications are generally mechanical, but occasionally they are chemical. For instance, in a specification issued not long ago, for a 13 horse-power high-speed engine, the only reference to the quality of the iron to be employed was that "no cast iron used in the engine should contain more than 0.5 per cent of phosphorus."

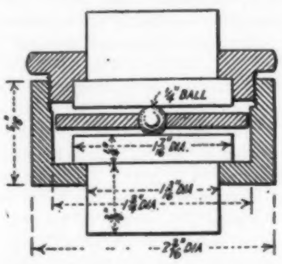


Fig. 1—Diagram of new device to determine hardness. Showing section of the container with the two test pieces and the test ball in position.

Certain makers in sending in their quotation said that this quantity of phosphorus was not in accordance with their usual practice, but they expressed their willingness to submit their metal to any reasonable mechanical tests. The engineer, however, was adamant, and so the order went past them.

The question of test specifications for cast iron in Great Britain is in a state of chaos, and the time is ripe for the drawing up of standard rules which shall at least have the result of making tests practiced in various works, comparative. Good work in this direction has already been done in America. There can be no two opinions regarding the benefits to be derived from a regular series of tests intelligently carried out. The results not only give a greater confidence in what is being done but lead often to much more economical working.

One of the causes which have militated against a wider application of testing in the foundry has undoubtedly been the great cost required to install the necessary machinery, a hydraulic tensile machine with its foundation, accumulator and pumps, transverse and hardness machines with proper house to accommodate them, making up a first cost bill which is generally considered prohibitive, besides which the machines generally require more than usual care in manipulation.

Engineers who have no knowledge of the founders' difficulties are apt to dub the members of the trade as non-progressive. But the tests employed show that some progress and effort is being made to meet the ever increasing exactions of engineering science. If engineers in general and draftsmen in particular would strive to know something even of the laws of crystallization, much better results could often be obtained with infinitely more economy and less anxiety to the foundryman.

Some of the other important points brought out by the author were as follows:

KEEP'S SHRINKAGE AND OTHER TESTS

The important tests which are of use as a guide to foundrymen are:

Keep's tests, shrinkage, deflection and transverse
Hardness test
Casting temperature or fluidity test
Measurement of volume and pressure of cupola blast
Impact test

Keep's test, as is now generally known, consists in casting ½-inch square bars between iron yokes, the ends of which are 12 inches apart. When the bars have cooled down the shrinkage is shown by the difference between the length of the bars and the gap in the yoke in which they were cast; this is usually measured by inserting a taper graduated wedge in the gap and measuring off the dimension of the space. This operation necessitates the bringing of the pattern plate yokes and bars into the office for measurement or vice-versa. To obviate this Mr. Broughall of Alfred Herbert, Ltd., has designed a micrometer on which the bars can be measured direct without application to the yokes and wedge. This necessitates the yokes being machined to a dead length and a daily trial of the yokes with a point gage, 0.003 inches oversize, the yokes being discarded when the point gage will enter, which in daily practice is not often.

The shrinkage test is quite a comparative one. Although it cannot be relied upon to give a definite determination of the silicon content of the metal, under normal conditions a shrikage of 0.183 inch is equal to 1 per cent silicon, and to take the other extreme 3.5 per cent silicon is associated with 0.123-inch shrinkage. It is surprising with low-silicon irons, where one is sailing near the wind as to machinability, what a great amount of change is expressed by a variation of 0.008 inch. It is obvious, then, that the test requires not only to be carefully taken, but intelligently diagnosed if the best results are to be obtained.

By splitting the ends of the bars which have been cast adjacent to the yokes a good impression not only of the chilling quality of the iron, but of the way in which it backs off into the gray, is obtained. The full benefit of this test is obtained, however, by testing the bars for deflection and transverse breaking load. One of the most important points to be watched in connection with the transverse test is the deflection obtained. Unfortunately, the machines usually employed for this test are rarely fitted with any apparatus that will give a reliable result, owing to their leaving no permanent record after the bar is broken. The machine designed by Keep for use with the ½-inch square bars, previously described, is fitted with a mechanism which, giving a permanent diagram to a scale of five times the actual deflection, meets all the requirements one could wish.

The following table gives average particulars of shrinkage, deflection and breaking load obtained with various classes of iron.

Class of Material	Shrinkage, Inches	Deflection, Inches	Breaking Load, Pounds
Tough strong iron	0.160	0.25	550
Hard strong iron	0.168	0.22	630
Soft iron	0.123	0.18	423
Mottled iron	0.207	0.11	375
White iron	0.226	0.08	250

From this it will be seen that to obtain a big deflection strong irons are necessary, whereas many believe that greatest deflection can be obtained with soft irons.

HARDNESS AND THE BRINELL TEST

Science has so far not succeeded in formulating a satisfactory definition of the term "hardness." A most desirable test for cast iron is for its *general* hardness—not surface hardness—or rather density, which for this metal is best described by Dr. Unwin as the resistance to penetration. The most handy and reliable form of test is therefore the drill test. As this test, like many other mechanical ones, is purely comparative, it matters very little—within reasonable bounds—as to the exact methods adopted to take it, so long as they are repeated in each test.

In connection with the Brinell hardness test, one of the objections lodged against it is the difficulty of measuring accurately the size of the indent; it undoubtedly requires very great care if accurate results are to be obtained. To avoid this the British Chuck & Piston Ring Company of Coventry, has invented a simple and ingenious device for its own use which is easy to manipulate, and has the further advantage that the test is a mean of two specimens.

Fig. 1 shows a section of the container with the two test pieces and the test ball in position; it will be seen to be so designed that the two outside faces of the test pieces are directly parallel and also that the ball is kept central. After the container has been screwed up tightly, the length overall is measured by a micrometer, the whole is then put under a drop hammer, which weighs 56 pounds, and is allowed a drop of 18 inches. After the blow has been given the container is screwed up tightly to take up the indent made in the specimens and the overall length again measured, the difference between it and the previous measurement being considered the hardness numeral.

Low-silicon cast iron is very prone to the effects of casting temperature, and some irons employed for such purpose are also liable to liquid contraction. A handy workshop test for casting temperature with this class of iron, which the author has used successfully for many years, consists in making bars of the general dimensions shown in Fig. 2. When cold the bars are broken through the line A, B, the condition of the fracture giving an indication of the temperature at which the metal was poured.

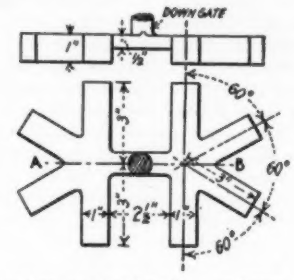


Fig. 2—Scheme of test bars for a workshop test for determining casting temperature.

A research to prove the effects of volume of blast upon cupola working has shown that pressure not only has an effect upon the quality of the metal, but also upon the quantity melted in a given time, the following formula for most efficient working being deduced:

$$\frac{W\ V\ P}{D} = 330$$

Where D = diameter of the cupola melting zone in feet; W = quantity of air in lbs. per minute. P = gage pressure of air in oz.

In every case where high-class work requiring low-silicon iron has to be dealt with, the cupola should be fitted with a recording blast pressure gage, and the revolutions of the blower should be capable of variation while at work.

IMPACT TESTING

While impact testing is not usually applied to cast iron; it is, however, beginning to be used, particularly on the Continent, in connection with Diesel engine work. A satisfactory test is on bars 40 mm. square (1.57 in.) supported on knife edges 160 mm. (6.3 in.) apart, and by dropping a weight of 12 kilos (26.5 lb.) from a height of 30 cm. (11.8 in.), increasing the height of drop by increments of 5 cm. (1.9 in.) until the sample breaks, the height at which the bar eventually fractures being taken as the impact figure. Attached to the weight, in such a manner as to strike the bar parallel to the supporting knife edges, and the center of same, is another knife edge. The face of all the knife edges should be rounded 1/16 in. radius. A result of 55 cm. (21.5 in.) is considered none too high for the work named, although this is quite a severe test. The maximum attained, as far as the author knows, has been 80 cm. (31.3 in.).

*From the *Iron Age*.

Achrodextrinase

CERTAIN species of *B. mesentericus*, cultivated in a nitrogenous medium, secrete an enzyme capable of liquefying starch. The best media for the production of the enzyme are feeding-cake, deprived of starch, and distillers' spent grains; from 1 kilo. of grains it is possible to obtain a quantity of the liquefying enzyme equivalent to that in 20 kilos. of good malt. The enzyme converts starch and erythrodextrin into achrodextrin very rapidly, but its saccharifying power is very restricted. If comparative conversions be carried out with soluble starch or starch paste at 40° C. until no further color reaction with iodine solution is obtainable, the proportion of maltose produced by the bacterial enzyme is only about 40 per cent, whereas with other diastases of vegetable or animal origin the proportion of maltose at the same stage is about 70 per cent. Achrodextrinase is also characterized by the fact that the products of the conversion of starch paste, carried out at 50° C. until 42 per cent of maltose is produced, possess a much lower viscosity than the products of the other diastases. Achrodextrinase is precipitated by alcohol and by ammonium sulfate; it acts most rapidly at 40° C. It is fully active in a medium neutral to methyl orange and is decidedly resistant to alkalinity, being still active in presence of 1 grm. per liter of sodium carbonate. On the other hand, it is very sensitive to an acid reaction, its activity being completely inhibited by the presence of 0.1 part of hydrochloric acid per 1,000. The bacterial diastase may be substituted for malt in the textile industry, and may be used for the production of dextrin syrups from the residues of starch factories. It also may be employed for removing starch in laundry work and a saving of 50 per cent of soap be may effected by its use. —From a note in *Journal of the Society of Chemical Industry*, in an article by J. EFFRONT, in *Comptes Rendu*.

Grain Size Measurements in Metals*

The Importance of Such Information

By Zay Jeffries, B.Sc., Met.E.

Of the two general methods for the testing of metals, namely, chemical and physical, the former has probably reached the higher state of perfection. Its value as a testing method and as a means of control of metal for specific uses is unquestioned. However, it is the physical and mechanical properties of metals which most interest the user. A metal is used for a certain purpose for the reason that it has certain properties which are essential for such purpose. Of two metals or alloys having desirable properties for a certain use, the one which can be produced the cheaper will be the more desirable metal or alloy to use from an economic standpoint. Frequently both chemical and physical specifications have to be met by the manufacturer of metals or alloys. Not infrequently the chemical specifications may be fulfilled and yet the physical specifications will be lacking, and, on the other hand, the physical specifications may be fulfilled and the chemical analysis may not be within the prescribed limits. Such a state of affairs has produced a growing tendency toward the elimination of chemical specifications. It is quite common at the present time especially in America, to specify certain properties, such as tensile strength, per cent, elongation, reduction of area, elastic limit, hardness, resistance to alternating stresses, electrical conductivity, etc., and to give the manufacturer a great degree of freedom as regards chemical composition. While this method might have its dangers, where it does not seem feasible to make both chemical and physical specifications, it is far better to trust to the physical tests than the chemical analysis.

With the chemical composition of a given metal or alloy remaining the same, the physical and mechanical properties may vary greatly, due to changes in structure. Theoretically, in such cases every change in structure should bring about a change in some or all of the physical properties.

By far the greater part of the microscopic work which has been done so far on metals and alloys has been qualitative in its nature. There are thousands of micrographs recorded which have been taken with the idea of demonstrating the qualitative differences. These micrographs represent only a small portion of the acutal samples which have been examined. While there is always a tendency to compare the samples quantitatively, such estimations have been made usually by direct visual comparison, either macroscopically or microscopically. In a great many cases, if metallographists would make an attempt to classify specimens, even according to the visual method, the profession would profit greatly by this information.

In metals and alloys consisting principally of one component, namely, commercially pure metals, compounds, or solid solutions, the quantitative estimation of the structure can best be made by determining the grain size. Grain size determinations are of no value unless certain physical or mechanical properties can be ascertained from them. The only way that grain size determinations can be interpreted is to correlate the grain size with the physical properties of the metal or alloy and with its performance in actual use. This is precisely the process by which the tensile, hardness and torsion tests have reached their present state of usefulness, and even after thousands of determinations these tests can only be approximately interpreted. It is therefore evident that grain size determinations will be of little commercial value until the proper correlations are made.

The present paper will point out certain cases where grain size measurements might be employed profitably, although, due to the decided lack of actual grain size measurements, it is possible at the present time to interpret only a few of such determinations. The more important methods for the determination of grain size will be briefly outlined with notes regarding their accuracy. A new method for grain size determinations, first used by author (the empirical constants now in use where this method is employed were determined by A. H. Kline and E. B. Zimmer, American Steel Foundries, Alliance, Ohio), which combines accuracy with speed and requires no apparatus which is not found in metallographic laboratories, will be outlined, together with methods for its application (Zay Jeffries, A. H. Kline, and E. B. Zimmer, "The Determination of Grain Size in Metals," *Bull. A.I.M.E.*, December, 1915; also *Iron Age*, February 3, 1916).

VALUE OF GRAIN SIZE DETERMINATIONS

In the amorphous cement theory, conceived by Beilby and ably championed by Rosenhain, Humphrey and others, it is considered that all metals or alloys in the solid state consisting of more than one allotrimorphic crystal are physical mixtures of the crystalline and amorphous phases of the components; for example, a pure metal having a fine-grained structure would be considered as a physical mixture of the crystalline and amorphous phases of that metal. The finer the grain the greater will be the quantity of the amorphous phase. The physical properties of the metal should vary with change in the quantity of the phases. The physical properties might not be in direct relation to the quantities of the two phases, since the amorphous phase in annealed metals is in such a position, namely, surrounding the crystalline phase, that a small addition to the amorphous material might make a relatively large difference in certain physical properties. Grain size determinations would seem to offer one of the best available methods for the determination of the relative quantities of the crystalline and amorphous phases.

As a means of interpreting physical or mechanical properties, grain size determinations offer a distinct advantage over some of the other methods now in common use. The tensile, compression, hardness, torsion and shearing tests, for example, break down the original structure of the metal, and by the mechanism of such destruction an attempt is made to interpret the various strength properties. Grain size determinations, where they can conveniently and accurately be made, are made on the metal in the state in which it is to be used.

It is well known that, other conditions being the same, the finer the grain in a given metal the greater the tensile strength and the elastic limit. The tensile test is by far the most used of any physical test in controlling metals used industrially. (The Brinell hardness test is replacing the tensile test in some places at the present time.) However, in most metals the change in grain size is more appreciable than the changes in any of the properties determined by the tensile test. In metals which have been submitted to high temperatures or are coarse grained for any other reason, grain size may prove to be a better indication of the life of the metal in use than the tensile test. This is especially true where vibration is encountered. The author has replaced the tensile test in the control of metal, for a certain use, by grain size determinations, and the latter method seems to be about five times as sensitive as the tensile test in estimating the life of the metal part in use.

W. Rosenhain makes the following statement in his book, "Introduction to Physical Metallurgy," in 1914, in considering the properties of coarse grained metals:

"The question then arises whether the increased size of crystals produced in a simple metal by prolonged heating is injurious or otherwise, so far as the useful properties, and more especially the mechanical properties, of the metal are concerned. There can be little doubt that within reasonable limits the mechanical properties of a simple metal are better the smaller the constituent crystals of which it is built up. Under the tensile test, coarseness of structure usually results only in a slightly lowered yield-point, while the ultimate stress and the elongation are little impaired, although the reduction of area at fracture is sometimes markedly less. . . . On the other hand, under both shock and fatigue tests, a coarse structure, even in a simple metal, gives unsatisfactory results."

C. H. Mathewson and Arthur Phillips also find that the grain size determination is more sensitive than the tensile test for the estimation of the strength properties in α-brass (*Bull. A.I.M.E.*, January, 1916, 33-39). They find in one instance a difference of about thirty per cent in the number of grains per square inch, and a difference of only four per cent in the tensile strength. From this it appears "that with due allowance for errors in counting, this method is more sensitive in detecting variations in strength properties than the tensile tests themselves."

Table I gives a comparison of the tensile properties, hardness and grain size between two α-brass samples of the same composition, according to Mathewson and Phillips.

Table I.—*Summary of Properties after Half-hour Anneal at 550°—Brass containing* 66.56 *per cent Copper,* 0.26 *per cent Lead,* 0.08 *per cent Iron.*

Initial reduction (per cent)	20	50
Initial reduction (per cent)	20	50
Elongation in 1 inch (per cent)	72	73
Reduction of area (per cent)	59.5	62.0
Ultimate strength (lbs. per square inch)	46,739	47,100
Scleroscope	10	10
Grains per square inch at 85 diameters	55.5	67.0

It is seen from above that grain size measurements might be employed profitably, especially to supplement the tensile tests.

A decreasing size of grain increases the hardness of a given metal or alloy. A good example of the relation between grain size and hardness is given by Fahrenwald ("A Development of Practical Substitutes for Platinum and its Alloys, with Special Reference to Tungsten and Molybdenum," *Bull. A.I.M.E.*, January, 1916). Pure gold was prepared, having four degrees of grain size, varying from extremely fine grained metal prepared from colloidal gold to coarse grained cast gold. The Brinell hardness varied from 23.8 in the coarse grained sample to 94.7 in the fine grained sample. Here, again, we have the quantitative measurements of the hardness, but not of the grain size. The grain size is referred to as coarse grained and fine grained, which are, of course, only relative terms.

It is probable that grain size measurements would throw some light on certain corrosion problems. While it has been reported that in certain cases metals are more resistant to corrosion in the cold-worked than in the annealed state, usually the latter offers the more resistance to corrosion (William E. Gibbs, "Corrosion of a Solid Solution: 70-30 Brass," contribution to a General Discussion on the "Corrosion of Metals," held before the Faraday Society, December 8th, 1915). It would seem that, other conditions remaining the same, the greater the quantity of amorphous material present, the greater would be the rate of corrosion. In this connection Leslie Aitchison makes the following statement ("Experiments on the Influence of Composition upon the Corrosion of Steel," contribution to a General Discussion on "The Corrosion of Metals," held before the Faraday Society, December 8th, 1915): "Whichever or whatever explanation be accepted as the cause of this amorphous layer, its presence can hardly be doubted, and its influence upon corrosion cannot be neglected." He also states that twinning in solid solutions may have an influence on corrosion.

Fine grained metals will volatilize more readily at high temperatures than coarse grained (Rosenhain and Ewing, "Intercrystalline Cohesion in Metals," *Journ. Inst. Metals*, 1912, viii). When metals are to be used at high temperatures, and where volatilization is a factor in the life or performance of the metal, such as in incandescent lamps and resistance wires for electric furnaces, it can be readily seen that coarse grained material will give less trouble from volatilization. While fine grained metals are stronger and have higher elastic limits than coarse grained metals at low temperatures, the reverse is true at relatively high temperatures.

In metals which have been cold worked the shape of the grains as determined by microscopic methods offers the best means for the quantitative estimation of the degree of cold work. Where it is possible to get this information from the working conditions, namely, the relative sizes of the metal piece before and after cold working, this should be done. Since the physical and mechanical properties of metals change greatly with the degree of cold work, the determination of the size and shape of the grains will be found valuable when dealing with such metals.

QUICK METHOD OF GRAIN SIZE MEASUREMENT BY THE AUTHOR'S METHOD

A quick way to make a grain size determination by this method has been developed. A circle 79.8 mm. in diameter is used. In making a grain size determination, one of the magnifications given in Table VI is used. In the third column is given the factor for each magnification, by which the equivalent number of whole grains within the circle is to be multiplied to obtain the number of grains per square mm.

The following example shows how this table is used:—Included grains, 61; boundary grains, 35; magnification, 100. Grains per square mm. $=[61+(0.6\times35)]2=164$.

Similar tables can be made for square inch calculations or for circles of different diameters.

Table VI

Magnification used	Diameter of circle Mm.	Factor
25	79.8	⅛
50	79.8	½
100	79.8	2.0
150	79.8	4.5
200	79.8	8.0
250	79.8	12.5
500	79.8	50.0
750	79.8	112.5
1000	79.8	200.0
1500	79.8	450.0
2000	79.8	800.0

*A paper read before the Faraday Society, and republished from the *Chemical News*.

APPARATUS AND MANIPULATION FOR GRAIN SIZE MEASUREMENTS

Any good metallurgical microscope with camera attachment can be used for grain size determinations. It is recommended that only even magnifications be used. For instance, if an observation is being made at a magnification of 469 diameters, the setting should be changed to 500 diameters.

Grain size measurements can be made on a screen or on a photograph. Either a ground glass or a piece of paper fastened to a clear glass may be used as a screen. A convenient system, where records of the determinations are kept, is to cut several pieces of thin typewriter paper so that they fit the clear glass screen, and draw a circle with the desired diameter near the center of each sheet. Fasten one of these pieces of paper to the clear glass screen by means of gummed labels, or otherwise, and project on to it the image of the specimen.

The circumference of the circle should be well within the image. Count and check separately the boundary grains and the included grains, make calculation for grains per unit area, and save the sheet of paper with check marks and calculations. This will serve as a permanent record of the determinations.

If the existence of a grain boundary is doubtful, often a slight change of focus will remove the doubt. It is therefore essential that the fine focusing screw be provided with an extension, so the focus can be changed while the operator examines the image on the screen.

Unless the room is rather dark, or the microscope lamp very strong, the operator will find it helpful to work under a cloth hood.

The specimen should be etched so as to bring out distinctly the grain or cell boundaries.

It has been found more satisfactory to make grain size measurements on a ground glass or paper screen than on photographs, for the reason that it is often hard to properly distinguish between adjacent grains in photographs, while a slight change of focus when examining the image of the metal itself will often remove any doubt.

Mathewson and Phillips (*Bull. A.I.M.E.*, January, 1916, 33) apply Heyn's method for grain size determinations in the following manner:

"Five parallel equidistant lines are ruled in one direction, and five in a direction at right angles to this upon a clear gelatine-coated glass plate. This plate is then placed upon the photomicrograph and counts made along the lines for a uniform distance of 2.75 in. From the five counts in each direction the average number of grains per inch in each direction is calculated."

SAMPLING

Since some metallographic specimens have several million grains exposed on one face the problem presents itself to obtain a representative sample of this face. The following rules are offered with the idea that they may be helpful:

1. Use such a magnification that about fifty grains will be included within the circle. It is better to have more than fifty grains included within the circle than less, but is always recommended that an even number of magnifications be used, even though the number of included grains should exceed 100.

2. Make at least five determinations at about equal intervals along a diameter of the specimen. The average of all of the determinations is taken as the final result. It is evident that if there is much difference in grain size between the edge and center of the specimen, the former should have the greater weight. Such a case, however, may come under Rule 4.

3. If the samples are small enough (for example, small wire) it is advisable to determine the total number of grains on transverse sections, and the total number for a given length on longitudinal sections. It is sometimes practicable to do this with larger coarse-grained specimens, either macroscopically or at low magnifications.

4. When one part of a specimen differs greatly from another part in grain size do not average the separate determinations, but record each and note the position of each determination by means of a freehand sketch.

5. In samples which have been cold worked the relative degree of cold work in any direction is expressed by the ratio of the length divided by the width of the grains. The actual amount of cold work in any direction is the ratio of the average dimension of the grains in that direction divided by the average diameter of the grains in the metal before working. If this ratio is less than 1, the grains in this dimension have been compressed; and if greater than 1, the grains have been stretched. For obtaining these ratios it is recommended that Heyn's method be used.

INTERPRETATION OF RESULTS

Distinction should be made between grain and cell. Any of the above methods may be used to determine cell size; for example, in steel, as well as the grain size in commercially pure metals, solid solutions, and alloys consisting largely of one component. However, with an alloy such as steel, where a network is encountered, the term "cell" should be used.

When a cold worked metal has been annealed and recrystallization has taken place, the resulting grains are not exactly equi-axed, but are usually longer in the direction of original deformation. From the grain size measurements it would be difficult in some cases to tell whether this persistent elongation of the grains was the result of moderate cold work without annealing or excessive cold work followed by annealing. However, the specimen usually furnishes a clue which will answer this question. If the elongation of the grains is due to a moderate amount of cold work without annealing, elongation of the individual grains will be the greater in the neighborhood of the points of application of the deformational forces; for example, in rolling, drawing, or hammering, the deformation of the individual grains will be greater near the surface than at the center. In metals which have been excessively cold worked and have undergone recrystallization by annealing this difference is not marked.

H. Baucke ("On Some Recent Microscopical Investigations of Copper," International Association for Testing Materials, Sixth Congress, New York, 1912) finds that in copper which has been severely cold worked and annealed at various temperatures the resulting recrystallized grains are longer in the direction of deformation until an annealing temperature of 900° C. is reached. If the annealing temperature is above 900° C. the grains are longer in the direction perpendicular to that of deformation. From the writer's experience it would seem that such a condition is not general in metals; in fact, there seems to be a great tendency for recrystallized grains, after severe cold working, to have their longest dimension in the direction of deformation, even after a long sojourn at relatively high temperatures.

Elongated grains which are not due to cold work are encountered in other places; for example, cast metals which have solidified progressively from the shell of the retaining vessel toward the interior of the mass of metal will have elongated grains, depending upon the direction of cooling.

Stead and Carpenter report this condition in the case of pure iron when cooled from above the upper critical temperature ("The Crystallizing Properties of Electro-deposited Iron," *J.I.S. Inst.*, No. 2, 1913, 119). By controlling the direction of cooling elongated grains can be produced with the length several times the width. In such cases these elongated grains have physical properties more like equi-axed than cold worked grains. This is no doubt due to the fact that the cold worked grains contain amorphous metal all through the mass, while the amorphous metal of elongated grains which have formed during the regular process of grain growth will be at the boundaries only.

Grains of various shapes can also be produced by controlling the direction of heating cold worked metals.

Except in these special cases elongated grains will indicate that the metal has been cold worked. In cold worked metals measurements parallel and perpendicular to the direction of working should show fairly constant ratios when determined by Heyn's method.

Metals which have been cold worked and subsequently annealed at temperatures well above the recrystallizing range are apt to have very even grain size (F. Robin, *Journ. Phys.*, 1914, iv, 37).

As mentioned in the earlier part of this paper the only way in which the proper interpretation of grain size determinations can be made is to correlate these measurements with the physical properties, chemical composition, and the life of the metals in use.

Wire Drawing*

By A. T. Adam

THAT wire is not a purely modern product is evident for the frequent mention of it in ancient writings. The earliest record dates as far back as 1700 B. C. Gold wire is mentioned in the 39th Chapter of Exodus as having been used to decorate the holy garments of Aaron. We find reference to it also in Homer and Pliny. Metal heads with imitation hair made of wire were recovered from the ruins of Herculaneum. Wire ropes also where not unknown to the ancients. The excavations at Pompeii brought to light a piece of bronze wire rope nearly 15 feet long and about 1 inch in circumference. This rope is now in the Museo Borbonio at Naples. It consists of three strands laid spirally together, each strand being made up of 15 wires twisted together. Its construction does not therefore differ greatly from that of wire ropes made today. It would seem, however, that these early specimens of wire were made by hammering metal (*i.e.*, gold, silver, and bronze) into thin sheets and cutting these into fine threads. The first mention of wire drawing occurs in the "History of Augsburg," dated 1351, and in the "History of Nuremburg," dated 1360, where we find the word "Drahtzieher" (wire-drawer). We hear of it soon after in France, but the first mention of it in Britain is in 1565 when a Saxon, named Christopher Shultz, and Caleb Bell came over with a number of foreigners, under the permission granted by Queen Elizabeth, to draw wire through drawing-plates and dig for metals. Caleb Bell had charge of a wire mill which was driven by a water wheel at Holywell, from which mill he supplied toilet pins to Queen Elizabeth.

In the reign of Charles I the production of wire had attained considerable proportions and an attempt was made by that monarch to introduce protection for the home industry by prohibiting the importation of foreign wire.

At the present day the world's output of wire is enormous. The proportion of the total steel product of the United States of America absorbed in the manufacture of wire rods has been estimated at no less than 20 per cent. Wire in all shapes and sizes is met with at every turn: in fences, nets, telegraph and submarine cable wires, railway signal wires, ropes, springs, pins, needles, bicycle spokes, musical instruments, etc., etc.

In this paper we are dealing chiefly with steel wire, and the following account of the processes involved in manufacture, has reference only to this commodity. The raw material of the wire mill consists of wire rods in coils which are obtained from the steel "ingot" and "billet" respectively by hot-rolling. It is difficult to define clearly a wire rod, because plants are now in operation which are drawing or rolling cold bars in round, square, or hexagon, etc., up to 2½ inches in diameter at least, probably more. In speaking of a wire rod, however, one generally means material which has been rolled hot to about ½-inch diameter and under.

Before the rods can be drawn through a die they must be freed entirely from scale or oxide. It is extremely important that every particle of scale be removed, otherwise the hole through which the wire is drawn will be torn out. The rods are therefore pickled in sulphuric or hydrochloric acid. The strength of the acid used depends on the conditions of working. When the coils are dipped in the pickling tank, it is usual to have a solution containing anything from 2 to 8 per cent of free acid, in which case the operation of cleaning takes about two hours. Slow cleaning is almost essential when the gage of the wire is small. A strong solution can be used when the gage is large or when the wire is drawn through the bath continuously instead of being dipped in the form of a coil. The process of pickling may be hastened by using a hot bath. The acid bath works best when it has been in operation a few days, *i.e.*, when the specific gravity has been increased by sulfate or chloride of iron. If the specific gravity be too high, however, the cleaning action will cease unless heat is used. I have found the percentage of free acid in a spent tank as high as in a freshly made up tank. The specific gravity of the former was 1.28, and of the latter 1.03.

Mechanical means have been tried to assist the acid in cleaning the higher class wires, but without much success. This is unfortunate because acid is apt to make the wire brittle unless great care is taken to remove it completely. When all the scale has been removed from the wire it is thoroughly washed with water from a hose. The cheaper qualities of wire are then dipped in hot lime and dried, but with the higher grade wires, which have to receive several passes through the draw-plate without annealing, it is necessary to give them a water coat. This is done by keeping the coils continually under a spray of water until a brown rust is formed; during this operation the wire must not be allowed to become dry. The wire is limed to neutralize any acid remaining and to prevent corrosion. The coil is then dried in a blueing oven at 100° C., where the last traces of acid should be driven off. The wire is then ready for cold drawing. The cleaning operation has to be performed not only on the raw wire rod, but on the drawn wire each time it has been annealed to facilitate further drawing.

The cleaned wire is taken to the wire-drawer's bench. This consists of a series of drums, technically known as "blocks," tapered from the bottom upwards. Each block revolves on a vertical spindle which projects through the top of the bench and all are driven by means of bevel wheels from one horizontal line shaft running beneath the bench. Each block can be started or stopped independently without stopping the line shaft. One end of the wire is pointed to enable it to be put through the die, the end is then gripped, and a short length is pulled through. The diameter or gage of this piece is accurately measured before starting. If correct a sufficient length of wire is pulled through to go round the drum or block which is at present out of gear. The

*Journal of the Society of Chemical Industry.

point end of the wire is gripped in a vise at the top of the block which is then dropped into gear, and the whole coil is drawn through from a swift near the bench. The reduction effected at each pass through the die varies from 5 to 20 per cent of the diameter according to the nature of the material. The draw-plates are made from the so-called "self hardening steels," *i.e.*, steels which do not require to be tempered, but harden when cooled in air. They contain a high percentage of carbon (about 2 per cent). Some of the alloy steels are used nowadays for draw-plates of special make: for example, one well-known make contains 14 per cent Cr and 3 per cent C; these elements form a very hard double carbide with the iron. The hole in the draw-plate through which the wire passes is first punched hot, then sized and shaped correctly when cold with hardened and tempered tapered punches. Very fine wires are drawn through jewelled dies, diamonds and rubies being chiefly used. Before the wire enters the die it passes through tallow or olive oil soap which acts as a lubricant. Some wires are drawn wet, in which case a liquid lubricant is used. Various "secret" lubricants are in vogue for the wet process, sour beer being a favorite ingredient of most of them. When the wire is to be drawn wet it is polished, to give a bright metallic surface, and is then coated with copper by immersion in a bath of copper sulphate. The copper being softer than the steel forms a kind of cushion between it and the die. It is drawn into the wire and gives it a yellow color. The process of drawing is repeated until the wire is finished or too hard to be drawn further without heat-treatment.

An improvement in the process of wire-drawing was made some time ago with the introduction of the continuous mill. In this plant the wire passes through one die after another without being run on to the "block" after each pass, the number of dies employed being limited by the amount of reduction possible before the wire requires annealing. In order to take up the strain, a power-driven barrel is placed between adjacent dies, and the wire is wound two or three times around each barrel in succession.

A pull is thus obtained from each revolving barrel sufficient to draw the wire through the die placed behind it.

The process of drawing metals into wire has a very marked effect on their physical properties. The metal loses ductility and becomes harder and more brittle with each pass through the die. The tensile strength is increased while the percentage elongation is decreased. The elastic limit is also raised, but within the limit of elasticity the modulus remains unchanged. The extent to which these changes take place naturally varies with the material. The most striking change is the extraordinary increase in tensile strength and elasticity. The hardness and brittleness do not increase in the same proportion. Steel which contains more than 0.5 per cent C if quenched in water from a red heat becomes glass-hard and brittle, but even the most severely drawn wire never becomes so hard and brittle as this, although the ultimate strength of hard-drawn wire is much higher than that of quenched steel. The tensile strength of the finished wire varies from about 40 tons to 170 tons per square inch according to the nature of the steel. A piano wire 0.0284 inch diameter, tested at Watertown Arsenal, showed the enormous strength of 211 tons per square inch. Such wires receive special heat treatment in order to enable them to stand the excessive cold work to which they must be subjected.

The hardening effect due to drawing sets a limit to the reduction that can be effected without annealing. Annealing alters the internal structure of the wire and completely obliterates the hardening effect of drawing, making the wire quite ductile again. It is not necessary to heat wire above the critical point of the steel, where the crystalline structure undergoes a complete transformation (this point lies between 700° and 800° C.) The effects of cold work can be almost entirely removed by heating to 600° or 650° C., but for high class work it is usual to anneal completely. Various modifications of the ordinary annealing process are in operation which constitute the more or less "secret processes" of the trade. The most important of these is what is technically called the "patenting process." In this process the wires are passed continuously through a long furnace, each wire having a separate flue or channel and cooled in air or sometimes in a lead bath. The main object in these processes is to produce in the steel the constituent known as "sorbite" which is tougher than the constituent known as "pearlite" found in slowly cooled steel. "Sorbite" is really a phase of "pearlite" produced by more rapid cooling. During these annealing processes the wire is oxidized and scale forms, which necessitates further pickling and causes considerable loss of metal. To minimize this many manufacturers exclude air during the heating operation either by annealing in sealed pots or by introducing non-oxidizing gases to the furnace.

In hot rolling the crystalline grains of a metal are not permanently elongated but merely broken up into a large number of smaller grains. The effect of cold drawing on the crystalline grains is quite different from this. The grains of a wire are elongated and, after several passes through the die, the structure, as seen in a longitudinal section, is quite fibrous in nature. If the wire were semi-transparent and could be viewed by transmitted light the structure would doubtless resemble that of some hemp fibers, *i. e.*, the elongated grains would be seen as parallel bundles or even running into one another, giving an interlacing structure.

It is not generally realized that hard and rigid bodies like the common metals possess a considerable degree of plasticity at atmospheric temperature. The fact that metals could be made to flow and to behave in other respects like fluids of high viscosity, such as pitch or glue, has been demonstrated in various ways, notably by Tresca, Spring, and Tammann. It is not, however, the most plastic or malleable metals which are most readily drawn into wire. According to Desch "the order of plasticity revealed by some of the most familiar metals is—K, Na, Pb, Tl, Sn, Bi, Cd, Zn, Sb," but these are not the most ductile metals. The order of ductility of the more important metals is given by Sir Roberts Austen as: Au, Ag, Pt, Fe, Ni, Cu, Zn, Sn, Pb. If this be true it would seem that wire drawing does not depend entirely on plasticity. Indeed, as we have said above, the constituent called "sorbite" in steel is said to be more suitable for wire drawing than the more plastic constituent called "pearlite." However, the rate at which traction is applied has great influence in testing plasticity and ductility.

The plastic deformation involved in drawing a hard crystalline solid like iron or steel into wire is not identical with that of an amorphous substance like pitch. The flow of pitch has been shown to be that of a fluid of high viscosity, while the microscope has shown that the flow of crystalline bodies is of quite a different nature.

The studies of Tyndall and Forbes on the behavior of glaciers were the first attempts to throw some light on the subject. It is well known that glaciers move like highly viscous fluids. This movement was explained by Forbes as being due to the plastic flow of ice-crystals under the action of slowly applied stresses. Tyndall opposed this view and stated that the flow was due to regelation, that is, the pressure on the ice, by lowering the melting point, caused the formation of a small quantity of liquid water which carried the grains of ice along with it, freezing and consequent cementing of the mass taking place as soon as the stress was relieved. For long controversy raged over the cause of glacier flow, and some metallurgists applied the regelation theory to explain the flow of metals. That regelation, under pressure, occurs in some metals such as bismuth is possible, but this is hardly a feasible explanation of the flow of such a metal as iron or steel. Nor is the probable existence of slight plasticity of the metal crystals themselves sufficient explanation of the rapid flow which occurs in wire drawing, swaging, or punching.

The discovery of "slipbands" in crystalline bodies by Ewing, Rosenhain, and others, together with the researches of Sir George Beilby on the nature of polish, indicate the most plausible explanation of the facts. If a piece of metal with a smooth, polished surface be strained or bent, a number of fine lines appear running in definite directions in each separate grain. These lines have been shown to be stepped in character, and their occurrence exactly resembles the production of step faults in geological strata. The direction of these "slipbands" is along the cleavage planes of the crystals. When a metal is subjected to alternating stresses these slipbands increase and finally form fissures, ultimately causing fracture of the material. In this way the phenomenon of "fatigue" in metals is explained; but it is well known that "fatigued" metals are hard and brittle like cold-drawn wire, and the experiments of Beilby offer an excellent explanation of this. These have shown that the effect of polishing is to cause a surface flow of the substance being polished, and have proved the existence of a thin layer of flowed structureless material strongly resembling in its bel[illegible] a highly viscous fluid. It would seem then that when a wire is drawn through a die slipping takes place in the metal along innumerable gliding planes, and sufficient viscous matter is formed to carry the crystalline material with it. When the traction is removed this sets in the form of an amorphous cement around the crystals. It is impossible by the most severe treatment to convert the whole mass into the amorphous modification. Hence, as already explained, there is a limit to the hardening effect of drawing. The hard amorphous material is not a stable modification and therefore cannot be truly called a phase. When the rigidity of the metal is decreased by heating, even to comparatively low temperatures like that of boiling water, partial recrystallization takes place, and this is more marked when the temperature is raised to 400° to 500° C. The examination of the micro-structure of steel wire affords considerable support to this amorphous cement theory, and this, taken in conjunction with the physical properties, seems to place the matter beyond doubt.

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